APPENDIX D

Other Species considerations for the Gulf of Alaska

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EXECUTIVE SUMMARY

Summary of Major Changes

This is the first assessment of Gulf of Alaska Other species. The purpose of this chapter is to highlight some of the available data for these species and develop some approaches toward evaluating the harvest levels and resource abundances. Input data included catch estimates by species group from 1990-1998, and 1984-1999 GOA triennial trawl survey biomass estimates for each species group. The proposed assessment model is a simple state-space model described in Appendix 3. Although changing the procedure for establishing the TAC of other species requires an amendment to the GOA FMP, we propose separate ABC and OFL levels for each species group within other species to ensure that less productive groups are not overharvested. These individual ABCs sum to slightly less than the recent aggregate TACs in the range of 14,000 t, but observed catches in each of the categories have never exceeded these proposed ABCs in the domestic fishery, with the exception of octopus catches in 1992 and 1997. We believe that cephalopod biomass is substantially underestimated by the bottom trawl survey, resulting in overly conservative estimates of ABC and OFL for these species groups, but we have no other data on which to base recommendations.

			Sharks	**Skates**	**Sculpins**	**Octopi**	**Squids**	Total
Tier 5		M	0.09	0.10	0.15	0.30	0.40	
model estimated 1999 biomass			34,214	72,164	30,259	550	2,134	
	F=0.75M	ABC	**2,309**	**5,412**	**3,404**	**124**	**640**	11,890
	F=M	OFL	**3,079**	**7,216**	**4,539**	**165**	**854**	15,853

Response to SSC Comments

From the October, 1999 SSC minutes: *Appendices B and C to the draft GOA SAFE progress in developing our understanding of the Other Species complex. These documents relate closely to the proposed Amendments 63/63 to the Fishery Management Plans to Revise Management of Sharks and Skates. Under the Gulf of Alaska FMP, the TAC for the other species complex is set at 5% of the sum of TACs of managed species. If an alternative is selected to remove sharks and skates from the Other Species complex, any allowable catch will be taken from a complex of much reduced size. This is because approximately 60% of the Other Species biomass is made up of sharks and skates.*

From the June, 1999 SSC minutes regarding shark and skate management: *During the SSC's discussion of this amendment, it was suggested that the Plan Team review the "other species" category generally to determine if adequate protection is provided for individual species to ensure their conservation.*

We propose separate ABC estimates for each species group, 1) to illustrate how Other species could be restructured to afford better protection to each species group, and 2) so that the SSC may evaluate the extent to which removing sharks and skates would affect allowable catch for the rest of the category.

Introduction

The Gulf of Alaska "other species" management category currently comprises multiple non-target species groups: sharks, skates, sculpins, smelts, octopi, and squids. Other species are considered ecologically important and may have future economic potential; therefore an aggregate annual quota limits their catch. Individual other species known or suspected to occur in the Gulf of Alaska are listed in Table 1. The species list was compiled from AFSC survey and fishery observer catch records, and is considered more comprehensive and up-to-date for the region than the general literature (Hart, 1973; Eschmeyer et al., 1983; Allen and Smith, 1988). However, this list may contain errors because species identification is difficult within this category, and taxonomy for certain groups is not fully resolved.

Information on distribution, stock structure, and life history characteristics is extremely limited for other species in the Gulf of Alaska. Some life history information is available for the same or similar species in other geographic areas. Given the wide diversity of species represented in this management category, we feel it is important to attempt to describe general life history characteristics at least at the species group level in order to evaluate the potential effects of fishing on other species. Therefore, we summarize the available information with the caveat that this should not substitute for future investigations specific to Gulf of Alaska stocks.

Sharks

Sharks are long-lived species with slow growth to maturity and large maximum size; therefore the productivity of shark stocks is very low relative to most commercially exploited bony fishes (Compagno, 1990; Hoenig and Gruber, 1990). Shark reproductive strategies are characterized by long (6 months - 2 years) gestation periods, with small numbers of large, well-developed offspring (Pratt and Casey, 1990). Many large-scale directed fisheries for sharks have collapsed, even where management was attempted (Anderson, 1990). The three shark species most likely to be encountered in Gulf of Alaska fisheries are the Pacific sleeper shark, *Somniosus pacificus*, the piked or spiny dogfish, *Squalus acanthias*, and the salmon shark, *Lamna ditropis*.

Little biological information is available for Pacific sleeper sharks, although they are considered common in boreal and temperate regions of shelf and slope waters of the north Pacific. Sleeper sharks are found in relatively shallow waters at higher latitudes, and in deeper habitats in temperate waters. Pregnant females have not been found, so reproductive mode is unknown, although ovoviviparity is suspected. One individual mature female sleeper shark had 300 eggs. Sleeper sharks grow to large sizes; individuals have been measured to 4.3 m, and lengths to 7 m have been observed under water (Compagno, 1984).

Spiny dogfish are demersal, occupying shelf and upper slope waters from the Bering Sea to the Baja Peninsula in the north Pacific, and worldwide in non-tropical waters. They are considered more common off the U.S. west coast and British Columbia than in the Gulf of Alaska (Hart, 1973). This species is commercially fished worldwide, and may be the most abundant living shark. Complex population structure characterizes spiny dogfish stocks in other areas; tagging shows separate migratory stocks that mix seasonally on feeding grounds in the UK, and separate stocks in BC and Washington state, both local and migratory, that don't mix (Compagno, 1984). Dogfish form large feeding aggregations, with schools often segregated by size, sex, and maturity stage. Male dogfish are generally found in shallower water than females, except for pregnant females which enter shallow bays to pup. This species is ovoviviparous with small litters of 1-20, and gestation periods of 18-24 months. While all parameters may vary by population, British Columbia female spiny dogfish are reported to mature at 23 years, and males at 14. Maximum age estimates range from 25-30 up to 100 years. Eastern north Pacific spiny dogfish stocks grow to a relatively large maximum size of 1.6 m (Compagno, 1984). Directed fisheries for spiny dogfish are often selective on larger individuals (mature females), resulting in significant impacts on recruitment (Hart 1973; Sosebee 1998).

Salmon sharks range in the north Pacific from Japan through the Bering Sea and Gulf of Alaska to southern California and Baja. They are considered common in coastal littoral and epipelagic waters, both inshore and offshore. Like other lamnid sharks, salmon sharks are active and highly mobile, maintaining body temperatures well above ambient water temperatures. Salmon sharks have been both considered a nuisance for eating salmon and damaging fishing gear (Macy et al., 1977; Compagno, 1984) and investigated as potential target species in the Gulf of Alaska (Paust and Smith, 1989), although little is known about their life history locally. In the western Pacific, females are estimated mature at 8-10 years and males at 5 years (Tanaka 1980). The reproductive mode for salmon sharks is ovoviviparous and with uterine cannibalism (Gilmore 1993), and litter size in the western North Pacific is up to 5 pups, with a ratio of male to female of 2.2 (Tanaka 1980). Maximum size has been reported at 3.0 m, but average size range seems to be between 2.0 and 2.5 m. This species lives at least 25 years in the western North Pacific (Tanaka 1980). An investigation is currently underway to determine demographics and population parameters for salmon sharks in the eastern North Pacific (K. Goldman, VIMS, personal communication).

Skates

Skate species are distributed throughout the north Pacific and are common from shallow inshore waters to very deep benthic habitats. Skate life cycles are similar to sharks, with relatively low fecundity, slow growth, and large body sizes. Although little specific life history information exists for most skate species, they are generally thought to have limited reproductive capacity, and thus be vulnerable to overfishing (Sosebee, 1998). Large skate species with late maturation (11+ years) are most vulnerable to heavy fishing pressure, with cases of near-extinction reported in the North Atlantic for the common skate *Raja batis* and the barndoor skate *Raja laevis* (Brander, 1981; Casey and Myers, 1998). Declines in barndoor skate abundance were concurrent with an increase in the biomass of skates as a group (Sosebee, 1998).

All skate species are oviparous, with one to seven embryos per egg case in locally occurring *Raja* species (Eschmeyer et al., 1983). The big skate, *Raja binoculata*, is the largest skate in the Gulf of Alaska. In California, female big skates mature at 12 years (1.3-1.4m), and males mature at 7-8 years (1-1.1 m). Maximum size is 2.4 m, with 1.8m and 90 kg common (Martin and Zorzi, 1993). The longnose skate, *Raja rhina*, achieves a smaller maximum length of about 1.4 m in California, and matures between ages 6 (males) and 9 (females). Maximum age reported for the longnose skate was 13 years, although there are many difficulties with ageing skates (Zeiner and Wolf, 1993). Little information is available on reproductive frequency in skate species, or on any *Bathyraja* species life history.

Sculpins

Sculpins (Cottidae) are relatively small, benthic-dwelling predators, with many species in the North Pacific. Despite their abundance and diversity, sculpin life histories are not well known in the Gulf of Alaska. Sculpin spawning generally occurs in the winter months; adhesive eggs are laid in nests, which are guarded by the male sculpin (Eschmeyer et al., 1983). The great sculpin, *Myoxocephalus polyacanthocephalus*, is a relatively large sculpin species which is commonly identified in fishery catches. In the western North Pacific, individuals grow to 70 cm and 8 kg. Female great sculpins from Kamchatka matured at 8 years (54-58 cm), males at 6 years (38-40 cm). Maximum ages reported for females and males were 13 and 9 years, respectively. Differences in fecundity and egg size were found between geographic areas, suggesting local stock structure. Mean fecundities for great sculpin were 60,000 to 88,000 eggs per gram body weight (Tokranov, 1985).

Smelts

Smelts (Osmeridae) are migratory pelagic schooling species, with high standing stocks and relatively short life spans (3-6 years). They only occur in the Northern Hemisphere, with large concentrations found at high latitudes. Wide fluctuations are characteristic of smelt stocks (Gjosaeter, H., 1997). Some smelt species are anadromous, while others spawn intertidally on coastal beaches, all with high to total post-spawning mortality (Eschmeyer et al., 1983). Environmental effects such as trends in water temperature can alter smelt productivity through changes in mean size, maturation rate, and the timing of spawning (Carscadden and Nakashima, 1997). Capelin (*Mallotus villosus*) and eulachon (*Thaleichthys pacificus*) are the most common smelts in the Gulf of Alaska. In the Barents sea, capelin are mature at 3-5 years ($>$ 14 cm). They migrate from winter feeding grounds to spawning areas in January-March. In March-April, spawning takes place over gravel or sand in 20-60 m of water. The demersal eggs hatch in 3-6 weeks. Immature individuals follow a seasonal migration route throughout the Barents sea until maturity. Although capelin may survive to spawn multiple times, in the Barents Sea this is considered unlikely due to high predation by cod on spawning grounds (Gjosaeter, H., 1997).

Octopi

In general, short lifespans of 1 to 5 years with a single reproductive period are reported for octopod species (Boyle, 1983). The North Pacific giant octopus, *Octopus dofleini*, is the largest of all octopods. It ranges from northern California to Japan in nearshore waters from low tide line to 200 m deep. In Japan, where octopus support directed fisheries, its life history has been extensively studied. Seasonal inshore-offshore migrations are reported, with mating occurring during autumn inshore in less than 100 m depth. Male octopus migrate back offshore and die, while females remain inshore, spawning 18,000 to 74,000 eggs in shallow water nests ($<$ 50 m) on rocky or sandy bottom between May and July. Eggs are brooded for 6-7 months; female octopus do not feed during this period, and die soon after the eggs hatch. Hatchlings are about 10 mm long, and are planktonic until growing to 20 - 50 mm, settling out to benthos in about March of the year following hatching (Roper et al., 1984). Life history in the eastern North Pacific is not as well known, but spawning may be more common in winter months (Hartwick, 1983). It is thought that giant octopus require 3 years to grow to an adult (mature female) size of 10kg, and that they live 3-5 years. We found no specific information about the life history of the flapjack devilfish, *Opisthoteuthis californiana*, or the smoothskin octopus, *Octopus leioderma.*

Squids

Like octopods, squid species have a single reproductive period; however, most squid lifespans are thought to be 1-2 years. Unlike octopods, squid are generally migratory pelagic schooling species. Squid have been described as “the marine equivalent of weeds,” displaying rapid growth, patchy distribution and highly variable recruitment (O’Dor, 1998). Many squid populations are composed of spatially segregated schools of similarly sized (and possibly related) individuals, which may migrate, forage, and spawn at different times of year (Lipinski, 1998). Most information on squids refers to *Illex* and *Loligo* species which support commercial fisheries in temperate and tropical waters. Of North Pacific squids, life history is best described for western Pacific stocks (Arkhipkin et al., 1995; Osako and Murata, 1983). The most commercially important squid in the north Pacific is the magistrate armhook squid, *Berryteuthis magister*. *B. magister* from the western Bering Sea are described as slow growing (for squid) and relatively long lived (up to 2 years). Males grew more slowly to earlier maturation than females. *B. magister* were dispersed during summer months in the western Bering sea, but formed large, dense schools over the continental slope between September and October. Stock structure in this species is complex, with three seasonal cohorts identified in the region. Growth, maturation, and mortality rates varied between seasonal cohorts (Arkhipkin et al., 1995).

Fishery Information

There is currently very little (if any) directed fishing for species in this category in the Gulf of Alaska. Other species are taken incidentally in target fisheries for groundfish, and aggregate catches of other species are tracked inseason by the Alaska Regional Office (Table 2). Other species catches have been relatively small each year since 1977, averaging less than 3% of total catch in the Gulf of Alaska. During the foreign fishery, catches of other species peaked in 1981 at 8,280 tons. There is an apparent second peak catch during the domestic fishery in 1992 at 12,313 tons, which represents the highest percentage of total GOA catch at 4.4%. Research trawl catches of other species between 1977-1998 are reported in Table 3.

Interpretation of reported catches of other species in the Gulf of Alaska is complicated by the changes to this management category which have occurred over time. Between 1981 and 1988, squid were reported separately from other species (but have been added in to totals reported here). In 1989, squid and Atka mackerel were added to the other species category. In 1991 - 1993, some catch of Atka mackerel was reported separately, but examination of catch records suggests that additional catch of Atka mackerel was reported as other species. Attempts were made to separate Atka mackerel catches out of other species totals in the years 1991 - 1993, but totals from this period should be regarded with caution. After 1993, the other species category stabilized in its current configuration, with Atka mackerel removed to its own reporting group. In 1998, a final rule on forage fishes was published removed smelts from the other species management category and placed them in a separate "forage fish" category. However, smelts are included with other species for the purposes of this assessment because they were still reported in the other species category throughout 1998. Grenadiers, eelpouts, and non-osmerid fishes in the forage fish category have never been included in the other species category, but catches of these groups were also estimated in this assessment.

Catch estimates by species group

Because annual other species catches are reported in aggregate, catches by species group or individual species must be estimated using data reported by fishery observers. Catches were estimated by species group for the recent domestic fishery, 1990 - 1998, using the following method: each year's observed catch by species group was summed within statistical area, gear type, and target fishery. The ratio of observed other species group catch to observed target species catch was multiplied by the blend-estimated target species catch within that area, gear, and target fishery. Total annual catch by species group has been relatively stable since 1990 (Table 4, Figure 1). Estimated annual species group catches are reported by target, gear, and statistical area in Tables 5 - 13. Annual estimated total catches for identified shark species are reported in Table 14. Catch patterns for each species group are discussed below.

Other species annual total catches estimated in this manner are generally lower than blend estimates of other species catch (Table 2 vs. Table 4). We attribute this to both targeting discrepancies and gear strata with no observer coverage (i.e., jig gear fisheries). Direct application of this method to estimate other species group catches using foreign and joint venture observer data is not possible due to differences in database structure. However, alternative methods of catch estimation will be investigated in future assessments.

Individual species catches are difficult to estimate. Within other species, only sharks (especially spiny dogfish, Pacific sleeper, and salmon sharks) are identified to the species level by observers with any regularity. Skates are almost always recorded as “skate unidentified”, with very few exceptions between 1990-98. At least 80% (by weight) of the observed sculpin catch each year was recorded as "sculpin unidentified," with the remainder of catch identified to the genus level (*Hemilepidotus*, *Myoxocephalus*, *Gymnocanthus*, *Triglops*). Only small amounts (<2%) of sculpin catch each year were identified to species. Likewise, octopus and squid are generally not identified to species in the NORPAC database--there is only one individual species code for squid, *Moroteuthis robusta*, and all other squid catch falls under the “squid unidentified” species code. Octopus can only be recorded as “octopus unidentified,” or “pelagic octopus unidentified.” Eulachon and capelin are recorded to species more often than sculpins, but in 1998 approximately 80% of osmerid catch was recorded as “smelt unidentified.” Observers are instructed to devote resources to higher-priority target species and prohibited species data collection, so they have limited time to devote to other species identification. In addition, fishery observers are currently not trained to identify skates, sculpins, squid, or octopus to species. This is due both to the relatively low priority assigned to these species and to the inherent difficulty in identifying North Pacific skate and sculpin species in particular.

The size distribution of vessels fishing in the Gulf of Alaska results in approximately 30% observer coverage overall, although some target fisheries (ie. rockfish) are prosecuted on larger vessels with 100% observer coverage. Therefore, in making these catch estimates, we are assuming that other species catch aboard observed vessels is representative of other species catch aboard unobserved vessels throughout the Gulf of Alaska. Because observer assignment to vessels is not at random, there is a possibility that this assumption is incorrect.

Elasmobranchs

Sharks and skates are caught in all Gulf of Alaska fisheries, and together represent the majority (50 to 80%) of estimated other species catches between 1990 and 1998. Shark catches alone have composed 9 to 20% of estimated other species catches. Spiny dogfish make up 49% of estimated shark catches on average, followed by Pacific sleeper sharks (19%), unidentified sharks (18%), and salmon sharks (12%, Table 14). Blue sharks, sixgill sharks, and brown cat sharks were rarely identified in catches. Salmon sharks are taken as rare bycatch in pollock fisheries (primarily pelagic trawl gear), while Pacific sleeper sharks and spiny dogfish are more often taken by bottom trawl and longline fisheries. The highest shark catches have been from the central Gulf of Alaska (GOA), statistical area 630.

The skate species group represents the highest proportion of other species catch weight for all years in the domestic fishery (43 - 65%). Skates are common bycatch in bottom trawl fisheries for Pacific cod, flatfish, and rockfish, and in longline fisheries for Pacific cod and sablefish. Most skate catch is from the central GOA, statistical area 630.

Sculpins

Sculpins are relatively common bycatch in Gulf of Alaska fisheries, representing 13 to 41% of estimated domestic other species catches. Sculpin species are most often caught in bottom trawl and pot fisheries targeting Pacific cod, and in flatfish trawl fisheries. Sculpin catches were highest in 1990 - 1992 in the western GOA, statistical area 610. From 1993 on, sculpin catches were generally lower and were concentrated more in the central GOA, area 630.

Smelts

Estimated smelt catches are the smallest component of other species catch, ranging from less than 1% to a maximum of 6% (1992) of the category by weight. Smelt species are taken as extremely rare bycatch in pollock fisheries, and are almost never observed in other target fisheries. Smelt catches were generally highest in the Kodiak region, area 620, although in some years catches in the central GOA (area 630) equaled or exceeded area 620 estimated catch.

Cephalopods

Cephalopod bycatch is rarely observed in Gulf of Alaska fisheries. Squid and octopus together represent 3-5% of estimated other species catches, with the exception of 1997 (14%). Most octopus bycatch occurs in pot gear fisheries directed at Pacific cod, although small amounts of octopus are caught in all bottom trawl fisheries. Squid are most commonly caught as bycatch in trawl fisheries for pollock, flatfish, and rockfish. Octopus and squid catches are highest in areas 610 and 630.

Grenadiers, eelpouts, and non-osmerid forage fishes

Grenadiers are very common bycatch in sablefish longline fisheries, with estimated catch weights in this fishery alone exceeding those of the entire other species category in each year. Grenadiers are also commonly observed in rockfish longline and trawl fisheries. Substantial grenadier catches are reported in all GOA areas, reflecting the distribution of observed deepwater longline fisheries. Conversely, eelpouts and non-osmerid forage fishes are rarely encountered in observed fisheries. Flatfish trawl fisheries account for most of the non-osmerid forage fish and eelpout estimated bycatch each year, which totals less than 15 tons annually, and is generally concentrated in the central GOA, area 630.

Survey Data

Triennial bottom trawl surveys conducted by the AFSC RACE division provide abundance estimates for species groups in the other species category between 1984 and 1999. Any discussion of biomass trends should be viewed with the following caveats in mind: survey efficiency may have increased for a variety of reasons between 1984 and 1990, but should be stable after 1990 (Robin Harrison, personal communication). Surveys in 1984, 1987, and 1999 included deeper strata than the 1990 - 1996 surveys; therefore the biomass estimates for deeper-dwelling components of the other species category are not comparable across years. Bottom trawl survey gear is probably most efficient for skates and sculpins, less efficient for sharks, and least efficient for smelts, squid and octopus species. Considering the burrowing habits and rocky inshore habitat of octopus, we assume that octopus biomass is substantially underestimated by this trawl survey. In one comparison of groundfish population estimation methods off central

California, an octopus species (*Octopus rubescens*) was the most abundant animal observed on video transects, but was not captured in trawls at all (Adams et al., 1995).

The average biomass of other species using all (6) survey biomass estimates is 160,000 tons (Table 15). The most recent estimate of other species biomass (1999) is 213,000 tons. Skates represent 30-40% of the other species biomass from all surveys and are the most common group in each year except 1984, when sculpin biomass was highest within the category. Total biomass for the other species category shows an increasing trend between 1984 and 1999 (Figure 2). This is the result of apparent increases in skate, shark, and smelt biomass, some of which may be difficult to resolve from changes in survey efficiency. Sculpin biomass appears relatively stable over this period, while squid and octopus biomass trends are difficult to assess with this survey. Alternate methods for evaluating survey trends are presented in SAFE Appendix E.

Individual species biomass trends were evaluated for the more common and easily identified shark and sculpin species encountered by the triennial trawl survey. In general, the increasing biomass trend for the shark species group is as result of increases in spiny dogfish and sleeper shark biomass between 1990 and 1999 (Figure 3). Salmon shark biomass has been stable to decreasing according to this survey, but salmon sharks are unlikely to be well sampled by a bottom trawl (as evidenced by the high uncertainty in the biomass estimates). It should be noted that both salmon shark and Pacific sleeper shark biomass estimates may be based on a very small number of individual tows in a given survey (Table 16). No salmon sharks were encountered in the 1999 survey.

Individual sculpin species display divergent biomass trends between 1984 – 1999. While the biomass of bigmouth sculpins (*Hemitripterus bolini*) has decreased over the period of the survey, great sculpin (*Myoxocephalus polyacanthocephalus*) biomass has remained relatively stable, and yellow Irish lord (*Hemiliepidotus jordani*) biomass has increased (Figure 4). The biomass of yellow Irish lords appears to have increased over time despite general stability in the number of hauls where they occurred, whereas bigmouth sculpins were encountered in fewer hauls each year (Table 17). Uncertainty in these estimates varies between years.

In addition to sharks and sculpins, we examined available biomass estimates for grenadiers (Macrouridae), which are not included in the other species category. The species most commonly encountered in the triennial trawl surveys was the giant grenadier, *Albatrossia pectoralis*. The Pacific grenadier *Coryphaenoides acrolepis* was present, but with much lower estimated biomass in all years. Survey coverage of deeper strata is particularly important to grenadier biomass estimates; therefore we consider the 1990 – 1996 survey estimates to be of little use for detecting trends in grenadier abundance. Biomass estimates from all years are reported (Table 18).

Additional survey databases will be investigated for possible use in future assessments to clarify trends in other species biomass. Longline surveys are conducted for halibut and sablefish by IPHC and Auke Bay lab, respectively. Initial investigation of the IPHC survey data suggested that it may provide a useful index of abundance for shark and skate species in certain areas around Kodiak. For smelts and other forage fishes, ADF&G small mesh trawl surveys (see Ecosystem chapter) may represent the best relative abundance information in certain geographic areas. Other Gulf of Alaska trawl survey information including pelagic surveys conducted by the Carrying Capacity Program at Auke Bay Lab will also be investigated.

Analytic approach, Model Evaluation, and Results

Please see GOA SAFE Appendix E for a description of an experimental modeling approach and its results for other species.

Projections and Harvest Alternatives

Allowable biological catch (ABC) and an overfishing limit (OFL) have never been formally calculated for other species in the Gulf of Alaska. Since 1990, the total allowable catch (TAC) of other species has been established as 5% of the sum of the TACs for all other assessed target species in the GOA. The other species TAC has never been exceeded with the current composition of the category (although it was reached when Atka mackerel were included in the category—this was the primary motivation for subsequently splitting them out). Because other species are currently taken only as bycatch in directed target fisheries, future catches of other species are more dependent on the distribution and limitations placed on target fisheries than on any harvest level established for this category. For example, changes in the allocation of quota by gear type in a major target fishery (i.e., Pacific cod longline vs. trawl) will result in different proportions and species composition of catches within the other species category. With this in mind, we outline options for other species "harvest alternatives."

The first option is to continue with the status quo of setting other species TAC as 5% of the TACs of all GOA target species. Under this option, no ABC or OFL is required, and the TAC cannot be estimated until all other groundfish species TACs are established for 2000. It should be noted that this option does nothing to prevent the entire TAC from comprising a single species group or even a single species within the other species category. This may ocurr if a directed fishery were to develop. In such a situation, it is possible that any OFL that might have been established for that single species (or species group) might be exceeded (Table 19), especially for less productive stocks.

A second alternative is to attempt to estimate an ABC and OFL for individual groups within the other species category, based on the extremely limited information available. Although this option will afford better protection to less productive components of other species, it requires that other species catch be monitored at the species group level instead of the current aggregate level. In addition, application of the tier criteria from FMP amendment 56 is difficult for species groups within other species. Tier 6 criteria for establishing ABC and OFL require a reliable catch history from 1978 to 1995. Although a catch history exists for the other species group as a whole during this period, we do not currently have reliable catch estimates by species group prior to 1990. Tier 5 criteria require reliable point estimates of biomass and natural mortality rate M. We are able to develop relatively conservative estimates of M for each species group based on literature values (see Appendix E). For certain groups within other species (cephalopods), our current lack of reliable biomass estimates makes ABC and OFL determination difficult, and potentially results in severe underestimates of allowable catch.

Several ABC and OFL options are available using the current tier 5 and 6 criteria for each species group within the other species category (Table 20). Since tier 6 criteria were probably not designed for bycatch species, and because we have a rather short time series of catches available, we do not recommend that ABC or OFL be based on Tier 6 criteria for other species groups. Within tier 5, we present ABCs and OFLs based on the most recent biomass estimate, the Appendix E model-estimated 1999 biomass estimate, and the 1984-1999 average biomass for each species group. We recommend the Tier 5 ABCs and OFLs based on model-estimated 1999 biomass for each species group:

	Sharks	**Skates**	**Sculpins**	**Octopi**	**Squids**
M	0.09	0.10	0.15	0.30	0.40
Est.1999 Biomass	34,214	72,164	30,259	550	2,134
ABC (F=0.75M)	**2,309**	**5,412**	**3,404**	**124**	**640**
OFL (F=M)	**3,079**	**7,216**	**4,539**	**165**	**854**

These ABCs and OFLs reflect our current understanding of the basic biology for each species group while protecting the less productive components of the category. In addition, they would allow similar levels of bycatch in target fisheries to those observed since 1990, assuming fishing patterns remain stable. We recognize that these categories still contain many species with different levels of productivity, so that even within these smaller ABCs there is a possibility of overfishing the least productive individual species. However, we think species group ABCs are an improvement over an aggregate TAC for this diverse category.

Other considerations

Understanding other species population dynamics is fundamental to describing ecosystem structure and function in the Gulf of Alaska, because each group in other species plays an important ecological role. The species groups in this category occupy all marine habitats from pelagic to benthic, nearshore to open ocean, and shallow to slope waters. Sharks are top predators, so fluctuations in their populations may have significant effects on community structure. Squid and octopus are highly productive, voracious predators which are in turn important prey for commercially important groundfish, sharks, and marine mammals. Smelts and other forage fishes are essential components in the diets of marine mammals, seabirds, and commercially important groundfish. Sculpins and skates are important benthic predators, and sculpins serve as prey for many groundfish species. Grenadiers, while not included in the other species category, may be the dominant fish in deeper habitats. They are caught in sufficient numbers to warrant additional attention, especially because they may be very long lived species (Andrews et al., 1999).

Summary

Catches of other species have been very small compared to those of target species in the Gulf of Alaska. It appears unlikely that the observed 1990-1998 bycatch of other species has had a negative effect on biomass at the species group level, according to the available trawl survey data. However, it should be clear from this assessment that data limitations are severe, and that further investigation is necessary to be sure that all components of other species are not adversely affected by groundfish fisheries. Furthermore, if target fisheries develop for any component of the other species group, effective management will be extremely difficult with the current limited information. We recommend the following harvest limits based on existing information.

M	0.09	0.10	0.15	0.30	0.40
Proj. 2000 Biomass	34,214	72,164	30,259	550	2,134
F_{ABC}	0.0675	0.075	0.1125	0.225	0.30
ABC	**2,309**	**5,412**	**3,404**	**124**	**640**
F_{OFL}	0.09	0.10	0.15	0.30	0.40
OFL	**3,079**	**7,216**	**4,539**	**165**	**854**

Regardless of management decisions regarding TAC and the future structure for other species, it is essential that we continue to improve species identification, survey sampling, and biological data collection for the species in this group if we hope to ensure their continued conservation.

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References

Adams, P.B., J.L. Butler, C.H. Baxter, T.E. Laidig, K.A. Dahlin, and W.W. Wakefield, 1995. Population estimates of Pacific coast groundfishes from video transects and swept-area trawls. Fish. Bull. 93: 446-455.

Allen, M. James, and Gary B. Smith, 1988. Atlas and zoogeography of common fishes in the Bering Sea and Northeastern Pacific. NOAA Technical Report NMFS 66. 151 pp.

Anderson, E.D., 1990. Fishery models as applied to elasmobranch fisheries. *In* Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.H. Gruber, and T. Taniuchi, eds.), p. 473-484. NOAA Technical Report NMFS 90.

Andrews, A.H., G.M. Cailliet, and K.H. Coale, 1999. Age and growth of Pacific grenadier (*Coryphaenoides acrolepis*) with age estimate validation using an improved radiometric ageing technique. Can. J. Fish. Aquat. Sci. 56: 1339-1350.

Arkhipin, A.I, V.A. Bizikov, V.V. Krylov, and K.N. Nesis, 1995. Distribution, stock structure, and growth of the squid *Berryteuthis magister* (Berry, 1913) (Cephalopoda, Gonatidae) during summer and fall in the western Bering Sea. Fish. Bull. 94:1-30.

Boyle, P.R, 1983. Commentary. *In* Cephalopod life cycles Vol.1: Species Accounts (P.R. Boyle, ed.), p. 411-412. Academic Press, London.

Brander, K., 1981. Disappearance of common skate *Raja batis* from Irish Sea. Nature 290: 48-49.

Carscadden, J. and B.S. Nakashima, 1997. Abundance and changes in distribution, biology, and behavior of capelin in response to cooler waters of the 1990's. *In* Forage fishes in marine ecosystems. Proceedings of the international symposium on the role of forage fishes in marine ecosystems, p. 457-468. Alaska Sea Grant College Program Report No. 97-01.

Casey, J.M. and R.A. Myers, 1998. Near extinction of a large, widely distributed fish. Science 281(5377):690-692.

Compagno, L.J.V., 1984. FAO species catalogue vol 4. Sharks of the world. An annotated and illustrated catalogue of sharks species known to date. Part 1. Hexaniformes to Lamniformes. FAO Fish. Synop., (125) Vol 4, Pt. 1, 249 p.

Compagno, L.V.J., 1990. Shark exploitation and conservation. *In* Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.H. Gruber, and T. Taniuchi, eds.), p. 391-414. NOAA Technical Report NMFS 90.

Eschmeyer, W.N., E.S. Herald, and H. Hammann, 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin Co., Boston: 336 pp.

Gilmore, R.G. 1993. Reproductive biology of lamnoid sharks. Env. Biol. Fish. 38:95-114.

Gjosaeter, H., 1997. The Barents Sea capelin stock (*Mallotus villosus*): a brief review. *In* Forage fishes in marine ecosystems. Proceedings of the international symposium on the role of forage fishes in marine ecosystems, p.469-484. Alaska Sea Grant College Program Report No. 97-01.

Hart, J.L., 1973. Pacific fishes of Canada. Fisheries Research Board of Canada, Bulletin 180. 740 pp.

Hartwick, B., 1983. *Octopus dofleini. In* Cephalopod life cycles Vol.1: Species Accounts (P.R. Boyle, ed.), p. 277-291. Academic Press, London.

Hoenig, John M. and Samuel H. Gruber. 1990. Life history patterns in the Elasmobranchs: implications for fishery management. *In* Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.H. Gruber, and T. Taniuchi, eds.), p. 1-16. NOAA Technical Report NMFS 90.

Lipinski, M.R., 1998. Cephalopod life cycles: patterns and exceptions. *In* Cephalopod biodiversity, ecology, and evolution (A.I.L. Payne, M.R. Lipinski, M.R. Clark and M.A.C. Roeleveld, eds.), p.439-447. S. Afr. J. mar. Sci. 20.

Macy, Paul T., Janet M. Wall, Nikolas D. Lampsakis, and James E. Mason, 1978. Resources of non-salmonid pelagic fishes of the Gulf of Alaska and Eastern Bering Sea. Part 1: Introduction. General fish resources and fisheries. Reviews of literature on non-salmonid pelagic fish resources. DOC/NOAA/NMFS Northwest and Alaska Fishery Science Center, unpublished manuscript.

Martin, L. and G.D. Zorzi, 1993. Status and review of the California skate fishery. *In* Conservation biology of elasmobranchs (S. Branstetter, ed.), p. 39-52. NOAA Technical Report NMFS 115.

O'Dor, R.K., 1998. Can understanding squid life-history strategies and recruitment improve management? *In* Cephalopod biodiversity, ecology, and evolution (A.I.L. Payne, M.R. Lipinski, M.R. Clark and M.A.C. Roeleveld, eds.), p.193-206. S. Afr. J. mar. Sci. 20.

Osako, M., and M. Murata, 1983. Stock assessment of cephalopod resources in the northwestern Pacific. *In* Advances in assessment of world cephalopod resources (J.F. Caddy, ed.), p. 55-144. FAO Fish. Tech. Pap. 231.

Paust, Brian and Ronald Smith, 1989. Salmon shark manual. The development of a commercial salmon shark, *Lamna ditropis*, fishery in the North Pacific. Alaska Sea Grant Report 86-01, Revised 1989.

Pratt, Harold, L., Jr. and John G. Casey. 1990. Shark reproductive strategies as a limiting factor in directed fisheries, with a review of Holden□s method of estimating growth parameters. *In* Elasmobranchs as living resources: advances in the biology, ecology, systematics, and the status of the fisheries (H.L. Pratt, Jr., S.H. Gruber, and T. Taniuchi, eds.), p. 97-109. NOAA Technical Report NMFS 90.

Roper, Clyde .F.E., Michael J. Sweeney, and Cornelia E. Nauen, 1984. FAO species catalogue. Vol. 3. Cephalopods of the world. An annotated and illustrated catalogue of species of interest to fisheries. FAO Fisheries Synopsis No. 125, Vol 3.

Sato, T., and H. Hatanaka, 1983. A review of assessment of Japanese distant-water fisheries for cephalopods. *In* Advances in assessment of world cephalopod resources (J.F. Caddy, ed.), p. 145-180. FAO Fish. Tech. Pap. 231.

Sosebee, K., 1998. Spiny dogfish and Skates. In Status of fishery resources off the northeastern United States for 1998 (S.H. Clark, ed.), p. 112-115. NOAA Technical Memorandum NMFS-NE-115.

Tanaka, S. 1980. Biological investigation of *Lamna ditropis* in the north-western waters of the North Pacific. *In*: Report of investigation on sharks as a new marine resource (1979). Published by: Japan Marine Fishery Resource Research Center, Tokyo [English abstract, translation by Nakaya].

Tokranov, A.M., 1985. Reproduction of great sculpin, *Myoxocephalus polyacanthocephalus* (Cottidae) in Kamchatka waters. J. Ichthyol. 24(4):119-127.

Zeiner, S.J. and P. Wolf, 1993. Growth characteristics and estimates of age at maturity of two species of skates (*Raja binoculata* and *Raja rhina*) from Monterey Bay, California. *In* Conservation biology of elasmobranchs (S. Branstetter, ed.), p. 39-52. NOAA Technical Report NMFS 115.

Table 1. Other species in the Gulf of Alaska, by scientific and common name; Sharks, skates, smelts, octopi, and squids. This list should be considered preliminary.

Scientific name	**Common name**	**Source of information** AFSC Survey	Fishery id.
Apristurus brunneus	brown cat shark		X
Cetorhinus maximus	basking shark	X	
Hexanus griseus	sixgill shark	X	X
Lamna ditropis	salmon shark	X	X
Prionace glauca	blue shark		X
Somniosus pacificus	Pacific sleeper shark	X	X
Squalus acanthias	spiny dogfish	X	X
Bathyraja abyssicola	deepsea skate	X	
Bathyraja aleutica	Aleutian skate	X	
Bathyraja kincaidi	sandpaper skate		X
Bathyraja interrupta	Bering skate	X	
Bathyraja lindbergi	commander skate	X	
Bathyraja maculata	whiteblotched skate	X	
Bathyraja minispinosa	whitebrow skate	X	
Bathyraja parmifera	Alaska skate	X	
Bathyraja rosispinis	flathead skate		X
Bathyraja trachura	black skate	X	X
Raja binoculata	big skate	X	
Raja rhina	longnose skate	X	X
Raja stellulata	starry skate	X	
Allosmerus elongatus	whitebait smelt	X	
Hypomesus pretiosus	surf smelt	X	
Mallotus villosus	capelin	X	X
Osmerus mordax	rainbow smelt	X	
Spirinchus starksi	night smelt	X	
Spirinchus thaleichthys	longfin smelt	X	
Thaleichthys pacificus	eulachon	X	X
Octopus dofleini	giant octopus	X	
Octopus leioderma	smoothskin octopus	X	
Opisthoteuthis californiana	flapjack devilfish	X	
Berryteuthis magister	magistrate armhook squid	X	
Gonatopsis borealis		X	
Gonatopsis makko		X	
Gonatus sp.		X	
Loligo opalescens	California market squid	X	
Moroteuthis robusta	robust clubhook squid	X	
Rossia pacifica	eastern Pacific bobtail	X	
Vampyroteuthis infernalis		X	

Table 1 cont'd. Other species in the Gulf of Alaska, by scientific and common name; Sculpins.

Scientific name	Common name	Source of information AFSC Survey	Fishery id.
Artediellus sp.		X	
Artedius lateralis	smoothhead sculpin	X	
Blepsias bilobus	crested sculpin	X	
Blepsias cirrhosus	silverspotted sculpin	X	
Dasycottus setiger	spinyhead sculpin	X	X
Enophrys bison	buffalo sculpin	X	
Enophrys diceraus	antlered sculpin	X	
Eurymen gyrinus	smoothcheek sculpin	X	
Gilbertidia sigalutes	soft sculpin	X	
Gymnocanthus galeatus	armorhead sculpin	X	X
Gymnocanthus pistilliger	threaded sculpin	X	
Hemilepidotus hemilepidotus	red Irish lord	X	X
Hemilepidotus jordani	yellow Irish lord	X	X
Hemilepidotus spinosus	brown Irish lord	X	
Hemitripterus bolini	bigmouth sculpin	X	X
Icelinus borealis	northern sculpin	X	
Icelinus burchami	dusky sculpin		X
Icelinus filamentosus	threadfin sculpin	X	
Icelinus oculatus	frogmouth sculpin	X	
Icelinus tenuis	spotfin sculpin	X	
Icelus euryops		X	
Icelus spiniger	thorny sculpin	X	X
Jordania zonope	longfin sculpin	X	
Leptocottus armatus	Pacific staghorn sculpin	X	
Malacocottus kincaidi	blackfin sculpin	X	X
Malacocottus zonurus	darkfin sculpin	X	
Microcottus sellaris	brightbelly sculpin	X	
Myoxocephalus jaok	plain sculpin	X	
Myoxocephalus polyacanthocephalus	great sculpin	X	X
Myoxocephalus quadricornis	fourhorn sculpin	X	
Myoxocephalus stelleri	frog sculpin	X	
Myoxocephalus verrucosus	warty sculpin	X	
Nautichthys oculofasciatus	sailfin sculpin	X	
Nautichthys pribilovius	eyeshade sculpin	X	
Psychrolutes paradoxus	tadpole sculpin	X	X
Psychrolutes phrictus	blob sculpin	X	
Radulinus asprellus	slim sculpin	X	
Rhamphocottus richardsoni	grunt sculpin	X	
Thyriscus anoplus	sponge sculpin	X	
Triglops forficata	scissortail sculpin	X	
Triglops macellus	roughspine sculpin	X	X
Triglops pingeli	ribbed sculpin	X	X
Triglops scepticus	spectacled sculpin	X	

Table 2. Summary of blend-estimated annual catches (tons) of other species.

Year	Foreign	JV	Domestic	Total
1977	4,725			4,725
1978	6,299			6,299
1979	4,507	38		4,545
1980	6,395	49		6,445
1981	8,247	33		8,280
1982	2,326	317		2,643
1983	2,523	395		2,918
1984	696	1,273		1,969
1985	103	2,253		2,356
1986	146	262		408
1987		182		182
1988		129		129
1989			1,560	1,560
1990			6,289	6,289
1991			5,700	5,700
1992			12,313	12,313
1993			6,867	6,867
1994			2,721	2,721
1995			3,421	3,421
1996			4,480	4,480
1997			5,439	5,439
1998			3,748	3,748

Sources: NORPAC Foreign blend tables, Domestic blend tables compiled by REFM, and 1998 GOA SAFE.

Table 3. Research catches (tons) of other species between 1977 and 1998. Catches do not include longline surveys.

Year	Sharks	Skates	Sculpins	Smelts	Octopus	Squid	Total
1977	0.14	2.15	7.09	2.33	0.04	0.06	11.80
1978	1.44	6.50	26.15	1.25	0.26	0.30	35.89
1979	1.00	0.94	4.44	0.06	0.44	0.19	7.07
1980	0.86	3.95	15.80	7.72	0.45	0.13	28.91
1981	2.23	8.90	17.47	6.69	0.23	2.91	38.43
1982	0.36	2.33	7.44	0.84	0.05	4.97	15.99
1983	1.03	3.73	2.19	1.23	0.08	0.33	8.60
1984	3.12	7.52	9.06	1.40	0.41	2.17	23.68
1985	0.96	5.58	5.10	7.71	0.10	5.05	24.50
1986	1.38	8.93	3.37	2.97	0.14	4.12	20.92
1987	3.55	6.87	7.74	2.89	0.25	3.13	24.43
1988	0.27	0.23	0.21	0.57	0.00	0.01	1.29
1989	0.87	1.79	0.37	2.55	0.01	0.13	5.73
1990	3.52	4.01	2.47	4.28	0.09	0.59	14.96
1991	0.15	0.28	0.00	1.65	0.00	0.03	2.11
1992	0.12	0.23	0.01	1.18	0.00	0.08	1.61
1993	5.03	7.77	3.11	4.98	0.18	1.37	22.44
1994	0.43	0.22	0.01	1.64	0.00	0.17	2.48
1995	0.57	0.07	0.00	0.72	0.00	0.02	1.37
1996	3.48	5.73	2.05	4.40	0.16	0.95	16.77
1997	0.52	0.30	0.01	1.06	0.00	0.04	1.94
1998	0.58	1.97	1.05	1.11	0.03	0.23	4.98
Totals	31.63	80.01	115.14	59.24	2.89	26.98	315.89

Table 4. Summary of estimated annual catches (tons) of other species+ by species group.

Year	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	**Total Other**
1990	274	1,124	969	54	79	60	2,560
1991	340	1,630	1,532	25	79	117	3,723
1992	517	1,835	1,392	264	151	88	4,248
1993	1,027	3,882	761	78	63	104	5,915
1994	360	1,770	514	15	39	39	2,737
1995	308	1,273	529	25	71	25	2,230
1996	484	1,868	739	17	79	42	3,229
1997	436	2,268	928	20	236	339	4,226
1998	669	1,596	502	135	105	74	3,081

Year	Other Forage	Grenadiers	Eelpouts
1990	0.26	9,694	10.70
1991	0.87	6,021	5.03
1992	0.15	12,897	11.99
1993	1.11	16,322	4.31
1994	5.35	34,180	2.17
1995	0.14	12,962	2.94
1996	3.52	12,618	3.12
1997	3.15	11,699	4.08
1998	2.43	14,499	4.59

Table 5. 1990 Estimated catches (tons) of Other species in the Gulf of Alaska by fishery and gear type, and by statistical area.

Fishery	Gear	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
Bottom Pollock	TWL	3,611	16,698	79.6	140.4	44.4	26.5	0.4	0.7	0.1	15	3.6
Pelagic Pollock	TWL	25,380	33,468	30.3	1.8	0.2	26.4	0.0	0.2	0.0	0	0.0
Pacific Cod	LGL	952	5,384	15.0	133.6	45.4	0.0	3.9	0.0	0.0	4	4.0
	POT	659	4,453	0.1	0.0	54.3	0.0	58.3	0.0	0.0	0	0.0
	TWL	10,370	51,704	55.2	386.8	665.6	0.2	6.5	0.5	0.0	0	1.2
Pacific Cod Total		11,982	61,540	70.3	520.4	765.3	0.2	68.7	0.5	0.0	4	5.2
Flatfish	LGL	9	8	0.1	1.2	0.0	0.0	0.0	0.0	0.0	2	0.0
	TWL	7,342	4,061	14.7	68.2	36.0	0.5	0.7	2.5	0.1	82	0.3
Flatfish Total		7,351	4,079	14.9	69.4	36.0	0.5	0.7	2.5	0.1	84	0.3
Rockfish	LGL	20	435	0.0	1.9	0.0	0.0	0.0	0.0	0.0	328	0.0
	TWL	13,597	17,452	8.2	54.5	111.1	0.3	8.3	51.0	0.0	499	0.9
Rockfish Total		13,617	17,887	8.2	56.4	111.1	0.3	8.3	51.0	0.0	827	0.9
Other	LGL	5	14	3.1	11.1	0.0	0.0	0.0	0.0	0.0	0	0.0
	TWL	1,493	287	1.3	35.5	8.4	0.0	0.4	0.5	0.0	23	0.0
Other Total		1,497	301	4.4	46.6	8.4	0.0	0.4	0.5	0.0	23	0.0
Sablefish	LGL	2,064	21,450	65.8	288.3	0.7	0.0	0.5	3.8	0.0	8,602	0.5
	TWL	820	164	0.3	0.6	2.4	0.1	0.2	1.1	0.0	140	0.1
Sablefish Total		2,883	21,616	66.1	288.8	3.1	0.1	0.7	4.9	0.0	8,741	0.6
Grand Total		66,322	155,597	274	1,124	969	54	79	60	0.3	9,694	11

Area	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
610	18,160	35,020	6.8	65.9	451.3	0.1	12.3	21.2	0.0	1,773	0.4
620	10,386	16,205	11.4	293.4	93.7	0.4	3.6	8.7	0.1	1,954	1.0
630	32,218	88,523	231.9	619.7	404.9	53.4	58.3	12.3	0.2	4,971	9.0
640	4,366	8,255	5.6	46.5	14.8	0.1	5.0	12.3	0.0	691	0.3
650	1,191	7,594	18.0	98.4	4.0	0.0	0.0	5.8	0.0	305	0.0
Grand Total	66,322	155,597	273.7	1,124.0	968.6	53.9	79.2	60.4	0.3	9,694	10.7

Table 6. 1991 Estimated catches (tons) of Other species in the Gulf of Alaska by fishery and gear type, and by statistical area.

Fishery	Gear	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
Bottom Pollock	TWL	4,555	13,570	57.1	106.9	57.4	4.0	0.4	9.0	0.5	383	0.8
Pelagic Pollock	TWL	32,517	80,497	53.4	2.3	1.5	14.3	0.2	24.9	0.1	196	0.0
Pacific Cod	LGL	1,306	7,324	58.7	540.9	26.2	0.0	2.4	0.0	0.0	0	0.0
	POT	948	10,487	0.0	0.1	48.9	0.0	65.1	0.0	0.0	0	0.1
	TWL	14,054	54,530	33.4	129.0	967.6	0.3	4.7	1.6	0.3	21	0.2
Pacific Cod Total		16,308	72,426	92.2	670.0	1,042.7	0.3	72.2	1.6	0.3	21	0.3
Flatfish	LGL	14	9	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1	0.0
	TWL	8,178	23,789	54.9	429.0	219.1	5.9	3.3	42.1	0.0	436	3.0
Flatfish Total		8,192	23,799	54.9	429.0	219.1	5.9	3.3	42.1	0.0	437	3.0
Rockfish	LGL	8	516	13.9	98.5	0.0	0.0	0.0	0.0	0.0	43	0.0
	TWL	7,576	15,799	7.0	82.1	121.9	0.0	2.0	38.8	0.0	207	0.6
Rockfish Total		7,584	16,710	20.9	180.6	121.9	0.0	2.0	38.8	0.0	249	0.6
Other	POT	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
	TWL	2,270	3,064	0.5	0.9	89.2	0.0	0.0	0.1	0.0	0	0.2
Other Total		2,276	3,066	0.5	0.9	89.2	0.0	0.0	0.1	0.0	0	0.2
Sablefish	LGL	1,651	20,399	61.4	239.9	0.5	0.0	0.8	0.0	0.0	4,711	0.1
	TWL	427	49	0.0	0.2	0.0	0.0	0.0	0.1	0.0	23	0.0
Sablefish Total		2,078	20,448	61.4	240.1	0.5	0.0	0.8	0.1	0.0	4,734	0.1
Grand Total		73,512	230,516	340	1,630	1,532	25	79	117	0.9	6,021	5

Area	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
610	30,211	77,937	17.5	135.3	1,164.8	0.3	9.3	64.7	0.1	1,329	0.4
620	7,725	31,154	14.5	163.2	89.9	14.2	10.4	6.6	0.0	971	0.2
630	31,080	101,998	284.3	1,115.9	266.1	10.0	58.6	29.9	0.8	2,744	4.0
640	3,533	11,306	4.8	60.7	10.1	0.0	0.4	13.7	0.0	573	0.4
650	724	6,569	18.2	148.7	1.3	0.0	0.2	1.8	0.0	346	0.0
680	227	1,528	1.1	6.1	0.1	0.0	0.0	0.0	0.0	58	0.0
Grand Total	73,512	230,516	340.32	1,629.92	1,532.30	24.50	78.80	116.70	0.87	6,021	5.03

Table 7. 1992 Estimated catches (tons) of Other species in the Gulf of Alaska by fishery and gear type, and by statistical area.

Fishery	Gear	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
Bottom Pollock	TWL	3,298	13,602	158.8	102.8	78.5	163.6	6.1	6.3	0.0	0	1.8
Pelagic Pollock	TWL	29,427	68,894	53.2	1.8	0.4	97.9	0.0	34.3	0.0	27	1.1
Pacific Cod	LGL	4,151	14,984	83.0	530.5	116.8	0.0	8.4	0.0	0.0	7	0.3
	POT	1,176	10,154	0.0	0.0	75.6	0.0	108.9	0.0	0.0	0	0.0
	TWL	11,806	49,408	19.9	212.5	733.8	0.0	12.9	0.0	0.1	13	0.7
Pacific Cod Total		17,133	74,868	102.8	743.0	926.1	0.0	130.1	0.0	0.1	20	0.9
Flatfish	LGL	39	5	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1	0.0
	TWL	7,936	26,007	122.4	514.2	266.2	1.9	9.9	16.5	0.0	705	4.7
Flatfish Total		7,975	26,013	122.4	514.4	266.2	1.9	10.0	16.5	0.0	706	4.7
Rockfish	JIG	1	338	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
	LGL	36	739	18.3	31.2	0.2	0.0	0.0	0.0	0.0	66	0.0
	TWL	9,137	18,614	4.1	87.2	50.8	0.1	1.9	25.7	0.0	298	2.7
Rockfish Total		9,173	19,694	22.5	118.4	51.0	0.1	1.9	25.7	0.0	363	2.7
Other	LGL	50	1	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0	0.0
	POT	0	7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
	TWL	9,186	13,665	6.3	11.9	69.7	0.0	0.3	0.4	0.0	0	0.2
Other Total		9,235	13,673	7.0	12.1	69.7	0.0	0.3	0.4	0.0	0	0.2
Sablefish	LGL	1,797	20,556	50.6	342.8	0.5	0.0	2.9	4.5	0.0	11,764	0.4
	TWL	589	9	0.0	0.1	0.1	0.0	0.0	0.0	0.0	17	0.0
Sablefish Total		2,386	20,565	51	343	1	0	3	5	0.0	11,780	0
Grand Total		78,637	237,309	517.35	1,835	1,392	264	151	88	0.15	12,897	11.99

Area	Observed Target	Blend Target	Sharks	Skates	Sculpins	Smelts	Octopus	Squid	Other Forage	Grenadiers	Eelpouts
610	30,488	69,580	11.4	235.9	766.2	0.3	22.8	4.7	0.0	4,413	2.5
620	12,297	38,647	162.9	269.8	60.7	179.0	12.0	14.3	0.1	598	1.1
630	33,375	112,098	312.6	1,121.3	550.8	84.2	114.9	50.3	0.0	5,854	8.3
640	1,946	8,597	4.0	83.4	12.1	0.0	0.7	14.6	0.0	1,795	0.0
649	25	586	1.94	14.34	0.00	0.00	0.88	0.00	0.00	0	0.00
650	504	5,860	24.47	110.77	2.67	0.00	0.00	3.75	0.00	237	0.01
659	1	1,938	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.00
Grand Total	78,637	237,309	517.35	1,835.47	1,392.44	263.54	151.26	87.75	0.15	12,897	11.99

Table 8. 1993 Estimated catches (tons) of Other species in the Gulf of Alaska by fishery and gear type, and by statistical area.

Fishery	Gear	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
Bottom Pollock	TWL	1,825	16,638	407.6	107.1	82.9	62.9	0.5	41.3	0.0	25	1.6
Pelagic Pollock	TWL	38,479	88,588	110.9	0.5	0.0	13.3	0.0	33.0	0.0	47	0.0
Pacific Cod	LGL	1,419	8,242	48.7	447.7	42.2	0.0	4.1	0.0	0.0	21	0.0
	POT	949	9,708	0.0	0.0	41.3	0.4	42.4	0.0	0.0	0	0.0
	TWL	5,718	30,508	21.3	132.1	198.3	0.0	5.2	1.9	0.0	2	0.1
Pacific Cod Total		8,085	48,461	70.0	579.8	281.9	0.5	51.7	1.9	0.0	24	0.2
Flatfish	LGL	84	29	0.0	0.7	0.0	0.0	0.0	0.0	0.0	84	0.0
	TWL	9,964	28,824	145.7	775.9	362.5	0.9	8.3	14.0	1.1	179	1.6
Flatfish Total		10,047	28,853	145.7	776.6	362.5	0.9	8.3	14.0	1.1	264	1.6
Rockfish	LGL	93	670	0.0	51.8	0.0	0.0	0.0	0.0	0.0	19	0.0
	TWL	7,704	14,199	2.4	31.8	30.4	0.0	1.9	13.4	0.0	430	0.8
Rockfish Total		7,796	14,997	2.4	83.6	30.4	0.0	1.9	13.4	0.0	448	0.8
Other	LGL	74	1	0.2	0.3	0.0	0.0	0.0	0.2	0.0	0	0.0
	POT	0	2	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0	0.0
	TWL	117	1,836	0.0	1,834.0	1.9	0.0	0.0	0.0	0.0	0	0.1
Other Total		191	1,839	0.2	1,834.3	2.6	0.0	0.0	0.2	0.0	0	0.1
Sablefish	LGL	2,750	22,255	290.2	497.2	0.4	0.0	0.8	0.4	0.0	15,456	0.1
	TWL	486	97	0.0	2.6	0.2	0.0	0.0	0.1	0.0	59	0.0
Sablefish Total		3,236	22,351	290.2	499.8	0.6	0.0	0.9	0.6	0.0	15,514	0.1
Grand Total		74,261	221,727	1,026.92	3,882	761	78	63	104	1.11	16,322	4.31

Area	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
610	15,696	43,792	18.4	1,896.1	132.6	0.0	10.8	4.1	0.0	3,239	0.2
620	17,128	37,684	155.8	250.5	35.5	48.2	4.5	56.7	0.0	2,624	0.3
630	37,866	121,342	648.5	1,317.6	586.7	29.3	47.2	40.6	1.1	6,259	3.7
640	2,928	7,939	24.7	166.6	5.6	0.0	0.2	2.2	0.0	2,634	0.1
649	53	671	0.0	21.1	0.1	0.0	0.6	0.0	0.0	0	0.0
650	588	8,060	138.35	126.87	0.55	0.00	0.00	0.78	0.00	1,548	0.04
659	1	2,240	41.16	102.91	0.00	0.00	0.00	0.00	0.00	19	0.00
Grand Total	74,261	221,727	1,026.92	3,881.78	760.93	77.50	63.21	104.29	1.11	16,322	4.31

Table 9. 1994 Estimated catches (tons) of Other species in the Gulf of Alaska by fishery and gear type, and by statistical area.

Fishery	Gear	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
Bottom Pollock	TWL	1,380	5,560	117.5	16.8	16.2	0.9	0.1	1.1	0.0	41	0.0
Pelagic Pollock	TWL	34,374	97,717	49.8	3.1	0.3	11.5	0.1	17.8	1.6	31	0.0
Pacific Cod	LGL	1,054	6,468	30.3	178.9	27.6	0.0	1.2	0.0	0.0	223	0.0
	POT	656	9,137	0.0	0.0	82.5	0.0	31.9	0.0	0.0	0	0.0
	TWL	2,946	28,147	5.5	222.8	164.7	0.0	1.1	0.1	0.0	0	0.2
Pacific Cod Total		4,656	43,845	35.9	401.8	274.8	0.0	34.2	0.1	0.1	223	0.2
Flatfish	LGL	13	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
	TWL	7,885	27,560	87.2	666.6	180.8	2.7	1.9	9.7	3.5	482	1.1
Flatfish Total		7,898	27,612	87.2	666.6	180.8	2.7	1.9	9.7	3.5	482	1.1
Rockfish	LGL	18	603	2.2	27.0	0.0	0.0	0.0	0.0	0.0	244	0.0
	TWL	6,984	11,479	1.7	34.9	24.5	0.0	1.7	10.2	0.0	429	0.7
Rockfish Total		7,002	12,399	3.9	61.9	24.5	0.0	1.7	10.2	0.0	673	0.7
Other	LGL	51	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
	TWL	43	1	0.3	1.0	0.0	0.0	0.0	0.0	0.0	0	0.0
Other Total		94	3	0.3	1.0	0.0	0.0	0.0	0.0	0.0	0	0.0
Atka Mackerel	TWL	2,449	3,264	0.0	0.0	17.1	0.0	0.0	0.0	0.0	0	0.0
Sablefish	LGL	1,192	20,065	65.3	617.6	0.2	0.0	0.6	0.0	0.2	32,650	0.2
	TWL	515	60	0.2	0.8	0.4	0.0	0.2	0.3	0.0	79	0.0
Sablefish Total		1,706	20,126	65	618	1	0	1	0	0.2	32,729	0
Grand Total		59,574	210,525	360.10	1,770	514	15	39	39	5.35	34,180	2.17

Area	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
610	10,877	36,757	22.0	63.3	198.7	0.0	12.5	4.1	0.0	1,901	0.6
620	12,867	42,417	59.9	425.4	55.7	2.4	1.4	8.2	1.8	2,517	0.3
630	30,295	106,915	231.0	838.1	256.6	11.5	21.1	22.7	3.5	8,864	1.2
640	5,149	14,546	13.7	175.0	2.7	1.2	0.7	3.8	0.0	5,481	0.1
649	62	922	0.00	0.00	0.75	0.00	3.08	0.00	0.00	0	0.00
650	324	7,651	33.59	267.81	0.02	0.00	0.00	0.26	0.00	15,416	0.01
Grand Total	59,574	210,525	360.10	1,769.67	514.43	15.11	38.83	39.14	5.35	34,180	2.17

Table 10. 1995 Estimated catches (tons) of Other species in the Gulf of Alaska by fishery and gear type, and by statistical area.

Fishery	Gear	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
Bottom Pollock	TWL	2,722	2,815	15.3	19.4	6.9	11.8	0.0	1.8	0.0	1	0.1
Pelagic Pollock	TWL	31,729	66,344	34.5	0.7	0.3	12.6	0.0	4.3	0.1	9	0.0
Pacific Cod	LGL	2,696	10,681	52.9	252.4	70.0	0.0	7.5	0.0	0.0	34	0.0
	POT	1,620	16,055	0.2	0.0	106.7	0.0	52.5	0.0	0.0	0	0.0
	TWL	10,775	38,396	13.8	147.3	129.8	0.0	7.5	0.1	0.0	0	0.4
Pacific Cod Total		15,091	65,203	66.8	399.7	306.5	0.0	67.5	0.1	0.0	34	0.4
Flatfish	LGL	16	104	0.2	6.4	0.0	0.0	0.0	0.0	0.0	214	0.0
	TWL	7,228	22,094	58.4	639.3	181.8	0.4	2.1	12.0	0.1	347	1.4
Flatfish Total		7,244	22,198	58.5	645.6	181.8	0.4	2.1	12.0	0.1	561	1.4
Rockfish	LGL	55	223	12.9	3.7	0.0	0.0	0.0	0.0	0.0	17	0.0
	TWL	9,605	15,383	15.4	45.9	31.1	0.1	0.6	6.6	0.0	428	0.4
Rockfish Total		9,661	16,125	28.3	49.6	31.1	0.1	0.6	6.6	0.0	446	0.4
Other	LGL	23	28	21.8	6.5	0.1	0.0	0.0	0.0	0.0	8	0.0
	POT	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
	TWL	51	24	2.8	19.9	0.9	0.0	0.0	0.0	0.0	0	0.0
Other Total		74	52	24.6	26.4	1.0	0.0	0.0	0.0	0.0	8	0.0
Atka Mackerel	TWL	171	161	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0	0.0
Sablefish	LGL	2,960	18,546	79.8	130.3	0.1	0.0	0.3	0.1	0.0	11,806	0.6
	TWL	401	104	0	1	0	0	0	1	0.0	98	0
Sablefish Total		3,361	18,651	79.84	131	1	0	0	1	0.00	11,904	0.65
Grand Total		70,068	191,549	307.89	1,273	529	25	71	25	0.14	12,962	2.94

Area	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
610	27,768	56,297	17.1	88.2	188.3	0.1	27.7	2.9	0.0	5,492	0.3
620	11,491	32,422	37.0	309.7	74.7	24.2	10.2	8.0	0.1	949	0.1
630	26,404	83,843	204.4	751.0	255.7	0.2	31.0	10.0	0.1	4,172	2.0
640	2,584	7,587	17.37	64.11	9.36	0.42	0.01	3.36	0.00	1,129	0.41
649	1,223	3,695	1.04	0.00	0.45	0.00	1.62	1.07	0.00	11	0.00
650	600	5,675	30.98	59.82	0.00	0.00	0.03	0.00	0.00	1,209	0.06
Grand Total	70,068	191,549	307.89	1,272.84	528.58	24.93	70.52	25.33	0.14	12,962	2.94

Table 11. 1996 Estimated catches (tons) of Other species in the Gulf of Alaska by fishery and gear type, and by statistical area.

Fishery	Gear	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
Bottom Pollock	TWL	1,860	4,204	19.2	74.4	8.6	2.5	0.0	7.7	0.6	2	0.0
Pelagic Pollock	TWL	16,737	42,957	39.4	1.3	0.1	10.2	0.0	10.3	2.0	16	0.0
Pacific Cod	LGL	1,332	9,908	15.1	341.1	130.4	0.0	9.7	0.0	0.0	5	0.0
	POT	881	12,040	0.0	0.0	96.5	0.0	50.6	0.0	0.0	0	0.0
	TWL	9,155	38,076	15.1	200.6	166.8	0.0	6.0	0.1	0.0	1	0.2
Pacific Cod Total		11,367	60,075	30.3	541.7	393.8	0.0	66.3	0.1	0.0	6	0.2
Flatfish	LGL	24	2	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1	0.0
	TWL	10,305	35,013	212.4	840.9	292.2	3.8	10.0	16.5	0.9	273	1.8
Flatfish Total		10,329	35,014	212.5	841.1	292.2	3.8	10.0	16.5	0.9	274	1.8
Rockfish	LGL	73	505	20.2	24.0	0.2	0.0	0.2	0.0	0.0	226	0.0
	TWL	7,638	14,154	1.6	39.5	25.1	0.1	1.1	6.1	0.0	354	0.8
Rockfish Total		7,711	15,082	21.8	63.4	25.2	0.1	1.3	6.1	0.0	581	0.8
Other	LGL	21	29	23.2	4.0	0.4	0.0	0.0	0.0	0.0	13	0.0
	POT	0	0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0	0.0
	TWL	47	219	15.2	191.2	11.3	0.0	0.9	0.0	0.0	0	0.2
Other Total		68	248	38.4	195.2	11.7	0.0	1.0	0.0	0.0	13	0.2
Atka Mackerel	TWL	807	1,186	0.3	5.9	7.0	0.0	0.0	0.0	0.0	0	0.0
Sablefish	LGL	2,372	15,964	122.1	144.4	0.0	0.0	0.8	1.0	0.0	11,710	0.1
	TWL	407	44	0	1	0	0	0	0	0.0	16	0
Sablefish Total		2,779	16,187	122.11	145	0	0	1	1	0.00	11,727	0.11
Grand Total		51,658	174,954	483.95	1,868	739	17	79	42	3.52	12,618	3.12

Area	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
610	15,441	48,558	39.8	168.7	211.3	2.0	15.7	10.0	0.0	3,523	0.3
620	13,429	44,171	42.2	564.1	179.8	7.0	13.6	9.1	2.8	1,127	0.3
630	18,359	67,018	313.9	989.9	340.2	6.3	47.7	18.9	0.6	4,891	1.9
640	3,246	6,798	32.37	65.01	7.25	1.40	0.43	3.08	0.09	1,081	0.69
649	362	998	0.49	0.00	0.15	0.00	1.67	0.66	0.00	0	0.00
650	822	5,144	55.08	80.59	0.21	0.00	0.22	0.08	0.00	1,996	0.04
Grand Total	51,658	174,954	483.95	1,868.32	738.83	16.67	79.35	41.80	3.52	12,618	3.12

Table 12. 1997 Estimated catches (tons) of Other species in the Gulf of Alaska by fishery and gear type, and by statistical area.

Fishery	Gear	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
Bottom Pollock	TWL	1,763	4,390	19.4	38.3	10.4	1.7	0.7	0.4	0.1	0	0.6
Pelagic Pollock	TWL	27,703	82,021	30.8	0.3	1.6	17.6	0.4	63.4	1.0	28	0.0
Pacific Cod	LGL	929	10,629	63.0	456.5	75.0	0.0	0.8	0.0	0.0	159	0.0
	POT	492	9,065	0.0	0.8	105.5	0.0	167.5	0.0	0.0	0	0.0
	TWL	7,118	42,770	26.3	446.1	226.0	0.0	21.5	0.6	0.0	0	0.5
Pacific Cod Total		8,539	62,488	89.4	903.3	406.4	0.0	189.8	0.6	0.0	159	0.5
Flatfish	LGL	33	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5	0.0
	TWL	6,762	23,237	130.0	910.3	386.0	0.8	12.9	10.4	2.0	366	2.8
Flatfish Total		6,795	23,240	130.0	910.3	386.0	0.8	12.9	10.4	2.0	371	2.8
Rockfish	LGL	53	458	2.0	5.7	0.0	0.0	4.1	0.0	0.0	23	0.0
	TWL	8,328	16,243	3.9	67.6	32.1	0.0	0.4	7.7	0.0	286	0.1
Rockfish Total		8,381	17,008	5.9	73.4	32.1	0.0	4.5	7.7	0.0	310	0.1
Other	LGL	34	56	37.0	7.9	0.0	0.0	0.0	0.0	0.0	14	0.0
	POT	0	65	0.0	0.0	12.3	0.0	24.7	0.0	0.0	0	0.0
	TWL	127	575	33.8	204.9	78.8	0.0	2.0	255.9	0.0	0	0.0
Other Total		161	699	70.8	212.8	91.1	0.0	26.7	255.9	0.0	14	0.0
Sablefish	LGL	2,143	13,971	89.6	129.1	0.0	0.0	0.7	0.4	0.0	10,818	0.1
	POT	2	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
Sablefish Total		2,333	13,978	89.6	129.1	0.0	0.0	0.7	0.4	0.0	10,818	0.1
Grand Total		55,870	203,823	435.76	2,268	928	20	236	339	3.15	11,699	4.08

Area	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
610	17,800	55,454	22.6	184.6	168.6	0.2	18.9	43.3	0.0	4,947	0.1
620	13,515	49,283	53.3	614.2	196.4	17.6	82.7	3.7	2.9	1,250	0.2
630	18,633	80,387	289.0	1,328.4	557.4	2.2	122.0	279.4	0.3	3,790	3.7
640	4,024	7,992	32.2	49.3	4.7	0.1	0.2	2.0	0.0	638	0.0
649	559	2,326	1.4	0.1	0.2	0.0	7.9	6.5	0.0	0	0.0
650	1,319	5,767	37.25	91.02	0.51	0.02	0.07	3.82	0.00	1,075	0.00
659	19	2,613	0.00	0.00	0.00	0.00	4.13	0.00	0.00	0	0.00
Grand Total	55,870	203,823	435.76	2,267.55	927.75	20.18	235.85	338.68	3.15	11,699	4.08

Table 13. 1998 Estimated catches (tons) of Other species in the Gulf of Alaska by fishery and gear type, and by statistical area.

Fishery	Gear	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
Bottom Pollock	TWL	3,870	3,443	27.3	15.0	2.6	38.4	1.1	4.8	0.1	0	0.0
Pelagic Pollock	TWL	39,199	120,741	102.4	7.8	0.4	94.3	0.1	45.5	1.2	0	0.0
Pacific Cod	LGL	465	9,621	124.3	453.2	173.8	0.0	23.6	0.0	0.0	0	0.0
	POT	1,212	10,510	0.0	0.4	61.2	0.0	73.8	0.0	0.0	0	0.0
	TWL	7,304	37,525	36.3	324.6	116.2	0.5	1.9	10.0	0.0	0	0.0
Pacific Cod Total		8,982	57,681	160.6	778.2	351.2	0.5	99.3	10.0	0.0	0	0.1
Flatfish	LGL	34	3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	1	0.0
	TWL	5,447	15,593	85.3	453.8	103.2	2.0	3.7	7.0	1.0	300	1.6
Flatfish Total		5,481	15,617	85.3	453.9	103.2	2.0	3.7	7.0	1.0	301	1.6
Rockfish	LGL	39	467	22.6	44.8	0.2	0.0	0.0	0.0	0.0	219	0.0
	TWL	9,168	16,074	3.9	31.1	40.8	0.0	0.3	6.6	0.0	248	2.0
Rockfish Total		9,206	16,753	26.5	75.9	41.0	0.0	0.3	6.6	0.0	467	2.0
Other	LGL	13	42	18.3	14.2	0.0	0.0	0.2	0.0	0.0	0	0.0
	TWL	39	279	159.3	115.9	3.1	0.2	0.0	0.0	0.0	0	0.9
Other Total		52	431	177.7	130.1	3.1	0.2	0.2	0.0	0.0	0	0.9
Sablefish	LGL	2,056	13,657	89.5	134.8	0.1	0.0	0.1	0.2	0.0	13,731	0.0
Grand Total		69,112	228,341	669.3	1,595.6	501.6	135.5	104.8	74.0	2.4	14,499	4.6

Area	Observed Target	Blend Target	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Other Forage	Grenadiers	Eelpouts
610	17,366	53,933	113.33	189	201	0	19	27	0.00	5,619	0.05
620	19,677	63,505	95.29	326	54	131	24	13	2.33	1,446	0.02
630	26,126	92,545	371.5	951.9	244.3	3.1	61.9	21.6	0.1	5,692	4.5
640	5,181	9,942	15.8	22.6	2.3	0.9	0.0	2.8	0.0	557	0.0
649	353	2,099	3.7	2.6	0.0	0.4	0.0	9.5	0.0	0	0.0
650	408	3,804	47.9	68.8	0.0	0.0	0.0	0.0	0.0	1,185	0.0
659	0	2,512	21.9	34.8	0.0	0.0	0.0	0.0	0.0	0	0.0
Grand Total	69,112	228,341	669.3	1,595.6	501.6	135.5	104.8	74.0	2.4	14,499	4.6

Table 14. Summary of estimated annual catches (tons) of sharks by species.

Year	Pacific Sleeper	Spiny Dogfish	Salmon Shark	Brown Cat Shark	Blue Shark	Sixgill Shark	Unidentified Shark	Total Sharks
1990	19.69	170.89	52.65	0.21		3.27	26.96	274
1991	49.36	141.23	41.58			4.21	103.93	340
1992	37.57	320.62	141.92	0.01			17.23	517
1993	214.78	383.36	89.16				339.62	1,027
1994	119.50	160.23	24.52			0.40	55.45	360
1995	62.97	140.63	54.93		7.54		41.81	308
1996	65.86	336.91	27.76		2.85		50.58	484
1997	118.12	233.48	24.63		3.25		56.28	436
1998	161.40	298.03	78.52	1.29	5.33		124.78	669
Total	849.25	2,185.37	535.68	1.52	18.98	7.89	816.64	4,415
% of Total	19%	49%	12%	0%	0%	0%	18%	100%

Table 15. Other species biomass estimates (tons) from AFSC triennial bottom trawl surveys.

Year	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	**Total Biomass**
1984	18,156	38,761	44,097	7,536	516	3,308	112,374
1987	24,049	36,398	31,742	16,526	203	5,083	114,000
1990	33,063	38,492	26,708	28,145	312	4,309	131,028
1993	50,025	63,219	25,460	35,210	599	9,476	183,989
1996	52,883	81,160	31,691	33,792	222	4,911	204,659
1999	51,355	112,935	30,827	14,890	992	2,096	213,094
Average	38,255	61,828	31,754	22,683	474	4,864	159,857

Table 16. Individual shark species biomass estimates (tons), with cv and number of hauls.

Year	Total hauls		Salmon shark	Spiny Dogfish	Sleeper Shark
1984	929	Hauls with catch	5	125	1
		Biomass	7849.3	10143.6	163.2
		cv of Biomass	0.522	0.206	1.000
1987	783	Hauls with catch	15	122	8
		Biomass	12623.3	10106.9	1319.3
		cv of Biomass	0.562	0.269	0.434
1990	708	Hauls with catch	13	114	3
		Biomass	12462.9	18948.7	1651.4
		cv of Biomass	0.297	0.378	0.660
1993	775	Hauls with catch	9	166	13
		Biomass	7729.2	33645.6	8650.7
		cv of Biomass	0.356	0.204	0.500
1996	807	Hauls with catch	1	99	11
		Biomass	3302.2	28479	21102.1
		cv of Biomass	1.000	0.736	0.358
1999	764	Hauls with catch	0	168	13
		Biomass		31863.8	19134.1
		cv of Biomass		0.138	0.402

Table 17. Individual sculpin species biomsss estimates (tons), with cv and number of hauls.

Year	Total hauls		Blackfin sculpin	Darkfin sculpin	Yellow Irish Lord	Great sculpin	Bigmouth sculpin
1984	929	Hauls with catch	93	69	267	90	226
		Biomass	503.7	820.1	14385.5	8818.9	15871.8
		cv of Biomass	0.244	0.322	0.142	0.205	0.102
1987	783	Hauls with catch	27	51	299	75	225
		Biomass	254.3	622.7	13531	6001.2	10194.4
		cv of Biomass	0.330	0.343	0.234	0.222	0.096
1990	708	Hauls with catch	74	4	153	26	117
		Biomass	535.9	58.3	11634.7	3814.7	8598.3
		cv of Biomass	0.261	0.827	0.317	0.421	0.258
1993	775	Hauls with catch	6	96	167	61	99
		Biomass	8.6	939.1	11739.3	5869	5583.4
		cv of Biomass	0.551	0.265	0.206	0.249	0.143
1996	807	Hauls with catch	0	119	152	45	50
		Biomass		477	17781.8	7325.4	4243.7
		cv of Biomass		0.145	0.440	0.283	0.199
1999	764	Hauls with catch	15	67	147	37	43
		Biomass	58.6	312.4	20220.3	3912.3	3974.1
		cv of Biomass	0.318	0.208	0.151	0.219	0.183

Table 18. Individual grenadier species biomass estimates (tons), with cv and number of hauls.

Year	Total hauls		Pacific grenadier	Giant grenadier
1984	929	Hauls with catch	6	81
		Biomass	106.2	169716.1
		cv of Biomass	0.593	0.175
1987	783	Hauls with catch	3	44
		Biomass	34.8	135978.1
		cv of Biomass	0.616	0.196
1990	708	Hauls with catch	2	22
		Biomass	99.2	20194.7
		cv of Biomass	0.693	0.622
1993	775	Hauls with catch	1	29
		Biomass	502	51413.8
		cv of Biomass	1.000	0.250
1996	807	Hauls with catch	0	38
		Biomass		51358.4
		cv of Biomass		0.195
1999	764	Hauls with catch	27	93
		Biomass	8241	386312.4
		cv of Biomass	0.113	0.097

Table 19. Possible catches under the recent TAC compared with 1999 Other species biomass estimates. Exploitation rates listed are calculated as if the entire other species TAC was taken for a given species group. The average of observed 1990-1998 catches for each species group is included for reference.

	1999 Trawl survey biomass	**1990-98 Average Observed Catch**	**1999 TAC**	**Maximum Possible Exploitation rate**	**F_{OFL}=M**	**Max Possible Exploitation Rate Exceed F_{OFL}?**
Aggregate	213,094		14,600	0.0685	?	?
Sharks	51,355	491	14,600	0.2843	0.09	Y
Skates	112,935	1,916	14,600	0.1293	0.1	Y
Sculpins	30,827	874	14,600	0.4736	0.15	Y
Smelts	14,890	70	14,600	0.9806	0.3	Y
Octopi	992	100	14,600	14.7237	0.3	Y
Squids	2,096	99	14,600	6.9650	0.4	Y

Table 20. ABC and OFL options for other species groups using Tier 5 and Tier 6 criteria. Smelts are excluded because they were removed to the forage fish category in January 1999. Recommended ABCs and OFLs for each species group (in boldface) are based on model-estimated 1999 biomass.

		Sharks	**Skates**	**Sculpins**	**Octopi**	**Squids**	**Total**
Tier 6							
0.75(Avg Catch '90-98)	ABC	368	1,437	655	75	74	2,610
Avg Catch 1990-98	OFL	491	1,916	874	100	99	3,480
Tier 5	M	0.09	0.10	0.15	0.30	0.40	
1999 survey biomass estimate		51,355	112,935	30,827	992	2,096	
F=0.75M	ABC	3,466	8,470	3,468	223	629	16,257
F=M	OFL	4,622	11,294	4,624	297	838	21,675
model estimated 1999 biomass		34,214	72,164	30,259	550	2,134	
F=0.75M	ABC	**2,309**	**5,412**	**3,404**	**124**	**640**	11,890
F=M	OFL	**3,079**	**7,216**	**4,539**	**165**	**854**	15,853
1984-99 average survey		38,255	61,828	31,754	474	4,864	
F=0.75M	ABC	2,582	4,637	3,572	107	1,459	12,357
F=M	OFL	3,443	6,183	4,763	142	1,946	16,477

Figures

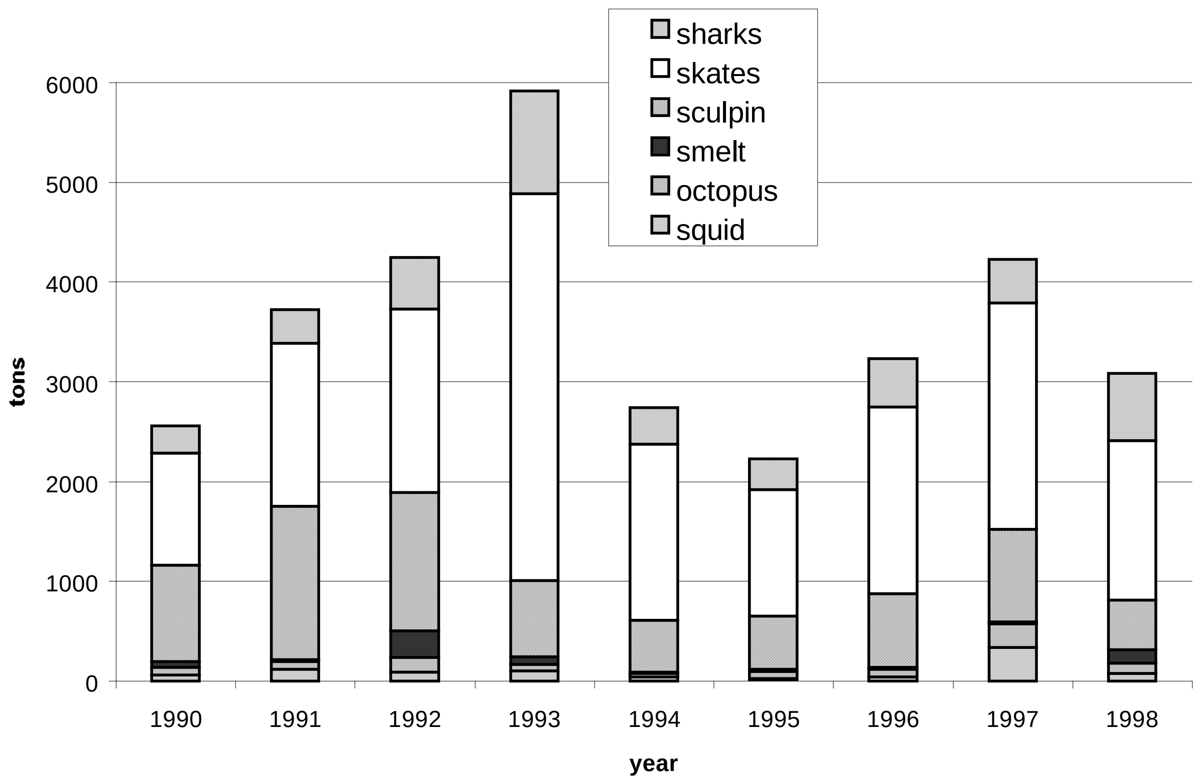

Figure 1. Estimated catch by other species group

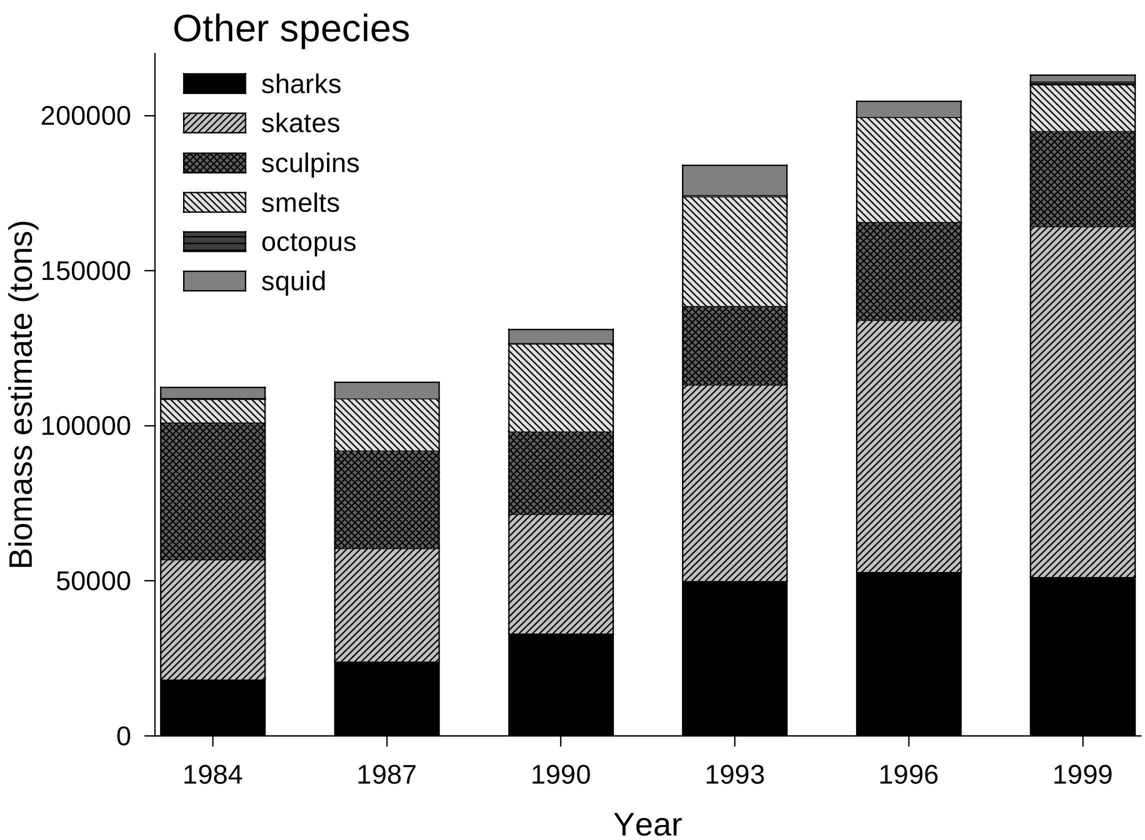

Figure 2. NMFS triennial trawl survey biomass estimates for other species, 1984-1999.

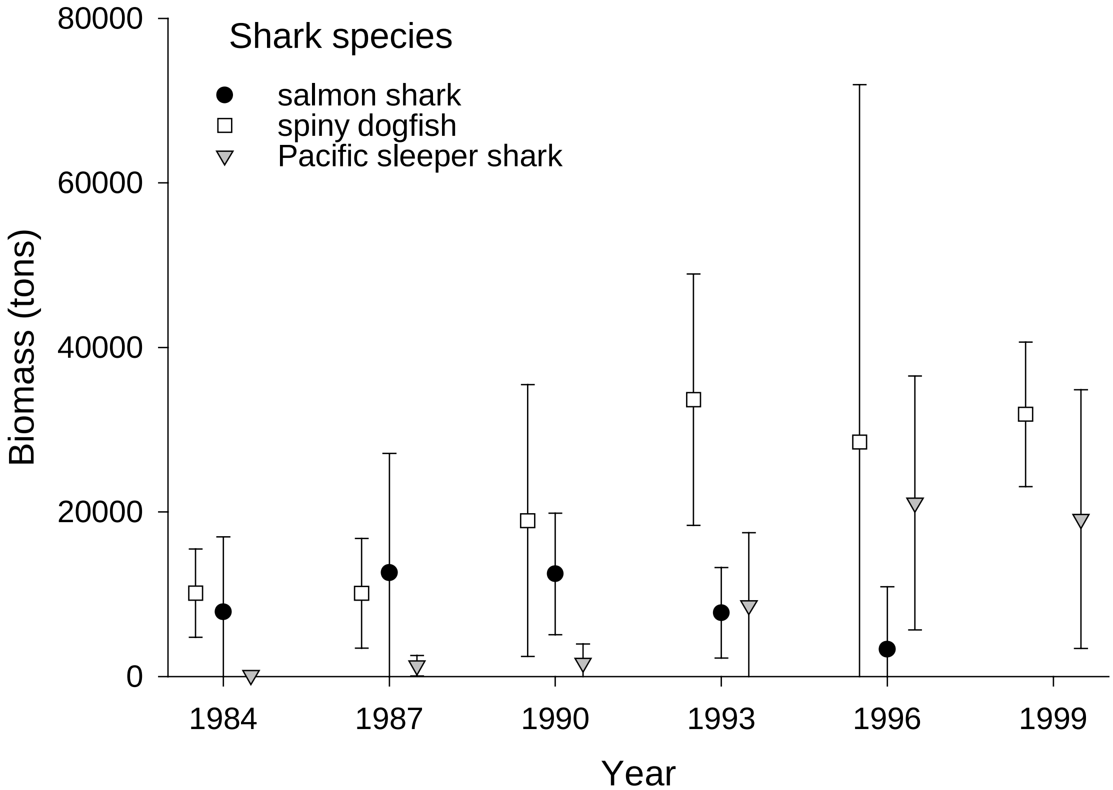

Figure 3. Trends in shark biomass from triennial trawl survey estimates. Error bars are 95% confidence intervals.

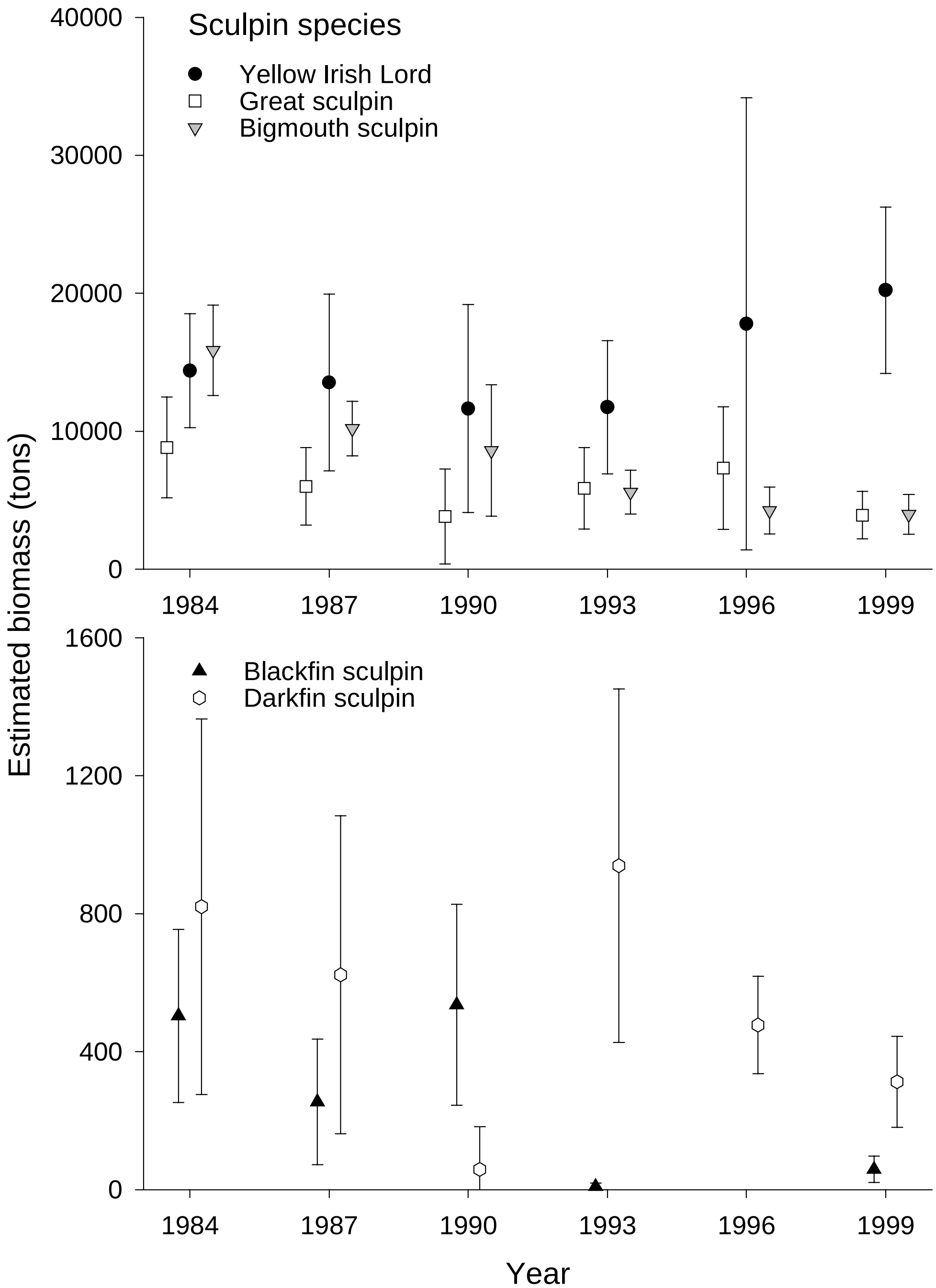

Figure 4. Trends in sculpin species biomass from triennial trawl survey estimates. Error bars are 95% confidence intervals.

APPENDIX E

An approach to analyzing multi-species complexes in data-limiting situations

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Abstract

The Gulf of Alaska “other species” management category comprises multiple non-target species groups: sharks, skates, smelts, squids, octopus, and sculpins. “Other species” are considered ecologically important and may have future economic potential; therefore an aggregate annual quota limits their catch. One management goal is to prevent overfishing of any single component of the category within the allowable aggregate catch. However, data on catch and abundance for these species are extremely "noisy" and result in estimates with high variance. The problem facing analysts is thus to find appropriate methods to deal with this “signal to noise” problem. Such methods should provide conservation recommendations that are robust to problems with the data while giving stability that managers desire. For example, in the Gulf of Alaska, managers may want to avoid linking conservation regulations directly to survey data recognizing that survey biomass estimates for certain species have high variability due to measurement error. We attempt to account for both observation error and process error in estimating biomass and exploitation rates for each species group using a simple state-space model. Here, process error was assumed to be different for species groups reflecting the diversity expected between short-lived smelts and long-lived sharks. We illustrate the potential problem of incorrectly specifying the ratio of process to observation error. In practice, specifying the

variance ratio may be less problematic since a species life-history traits are generally known, as are the problems associated with survey abundance estimates.

Introduction

Fisheries managers are asked to provide advice for an increasing number of species and species groups in many areas. Technical guidance for implementing National Standard 1 under the Magnuson-Stevens Fisheries Conservation and Management Act suggests that biological reference points—or proxies—and harvest control rules should be developed for each stock in a mixed stock complex, even though information may be limited (Restrepo et al., 1998). The precautionary management approach adopted by the Act applies to non-target as well as target species. Here we present an analysis that may help address these issues for the Gulf of Alaska other species complex, which includes sharks, skates, sculpins, smelts, squid, and octopus.

The North Pacific Fishery Management Council (NPFMC) sets an annual quota (TAC) for the entire other species category. The other species TAC is currently established as 5% of the sum of all target species TACs in the Gulf of Alaska, which achieves the management goal of limiting fishing pressure on the aggregate complex. Additional management goals are to prevent overfishing of individual groups within the complex while avoiding premature closure of target fisheries due to inadequate data. The NPFMC defines overfishing limits (OFLs) as exploitation rates using a tier system based on information quality criteria. Defining an OFL exploitation rate requires abundance and catch estimates for the stock in question. The guidelines for arriving at OFL (via exploitation rates) in data-poor situations minimally require natural mortality rate estimates for setting the level. We explore some natural mortality-derived OFL estimates for each species group based on literature searches from other areas and/or for closely related species.

The purpose of this paper is to present an alternative method that may be useful for deciding future management actions. The two key questions for management are:

- Have we exceeded OFL for any species group in “other species” in the past?
- What is the probability of exceeding OFL for any species group in other species next year?

We present some preliminary analyses of how one might approach answering these questions, and hope to highlight where appropriate re-classifications (in terms of management groups) may be made and also what types of information would most improve the situation regarding the problem of limited data.

Methods

Available data

Fishery

The data for “other species” is limited in scope and quantity. For the Gulf of Alaska, catch by species is derived from a fleet that is only about 30% covered by observers. Furthermore, the breakdown to the species categories varies where “sharks” may be a handful of species while “sculpins” may represent a few dozen different species. The method for estimating catch by species group is given in GOA SAFE Appendix D. Briefly, catches were estimated by species group for the recent domestic fishery, 1990 - 1998, using the following method: each year’s observed catch by species group was summed within statistical area, gear type, and target fishery. The ratio of observed other species group catch to observed target species catch was multiplied by the official total catch (observed + unobserved) of target species catch within that area, gear, and target fishery as estimated by the NMFS Alaska Regional Office “blend” algorithm. Other species catch estimates are summarized in Table 1 and Fig. 1.

Survey

NMFS has conducted triennial bottom trawl surveys in the Gulf of Alaska since 1984. These surveys are multi-species in nature but are generally designed for sampling demersal groundfish species between 50 and 500 meters depth. For the “other species” groups, there is a large amount of variability in the utility of these surveys. For example, sculpins and skates are likely to be well sampled by this type of trawl gear, whereas more pelagic species such as squid and smelts may only be captured during gear setting and retrieval. Similarly, octopi are unlikely to be fully available to the gear since most of their time is spent in crevasses and holes. We assume that the survey swept-area biomass estimates for octopus are substantial underestimates of true octopus biomass, but we make no attempt to compensate for the underestimation in this analysis. For all “other species” groups, we used the biomass as estimated from the standard NMFS swept-area computations together with their estimates for the sampling variance. The species group biomass estimates are shown in Fig. 2 and Table 2.

Life history information from similar species

Since there are no directed studies on most of these species (and certainly none for these "species groups") we relied on the literature for values of interest (GOA SAFE Appendix D). The values important for this model specification are given in Table 3.

Model Specification

We develop a simple application of state space dynamics where we model our observations of biomass along with true biomass which is unobservable. The observation model for species k can be expressed as

$$Y_{k,t} = f\left(\theta_{k,t}\right) + v_{k,t},$$
$$v_{k,t} \sim N(0, \sigma^2_{v_{k,t}}),$$

where $Y_{k,t}$ is the swept-area survey estimate of absolute biomass with sample variance $\sigma^2_{v_{k,t}}$.

The state model can be written as

$$f\left(\theta_{k,t}\right) = f\left(\theta_{k,t-1}\right) e^{w_{k,t}},$$
$$w_{k,t} \sim N(0, \sigma^2_{k,w}).$$

Here we consider the values of $f\left(\theta_{k,t}\right)$ as a simplistic representation of the "true" but unobservable stock size for each species group. For the time being $f\left(\theta_{k,t}\right)$, the "dynamics" part of our "population dynamics model" will be entirely subsumed within the process error term $w_{k,t}$. That is, this "natural variability" term incorporates the expected effects of recruitment, growth, movement, and mortality for each species group relative to other groups. Therefore, in this simplest model formulation, $f\left(\theta_{k,t}\right) \equiv \theta_{k,t}$.

For species group k in year t, the exploitation rate is simply

$$\hat{U}_{k,t} = \frac{\hat{C}_{k,t}}{\hat{\theta}_{k,t}}$$

where

$$\hat{C}_{k,t} = \overline{C}_k + \delta_{k,t},$$
$$\delta_{k,t} \sim N(0, \sigma^2_{\delta_k}).$$

Since the purpose of this exercise is to provide advice for management purposes, we can project this model forward to future years (along with the estimated uncertainty). For the projection year of interest (here the year 2000) we express catch as

$$\hat{C}_{k,2000} = \overline{C}_k + \delta_{k,2000}$$

and compute the projected exploitation rate for 2000 as above. The error term for the projection year has the same variance ($\sigma^2_{\delta_k}$) as for the other years. For all years, the variance term was derived from the catch estimates (Fig. 1) for each species group. Note that the uncertainty in both biomass and catch are maintained since $\hat{\theta}_{2000}$ is also uncertain.

Assumptions

As with any model, there are a number of important caveats associated with the assumptions:

1) The survey efficiency is constant over time;
2) Estimates of survey variance are correct;
3) Estimates of "natural variability" are reasonable and constant over time;
4) The catch estimation method is accurate.

One purpose of this model is to provide diagnostics for problems associated with these assumptions. We provide an example demonstrating sensitivity to alternative assumptions about 2) and 3) and give an illustration of how 1) can be assessed.

Parameter estimation

State-space models like the one we have specified are generally amenable to estimation via elegant methods such as the Kalman Filter (Pella 1993, Schnute 1994, Kimura *et al.* 1996, Thompson 1998). However, we found that the Kalman filter becomes more complicated when survey observations occur at irregular intervals. Consequently, for this initial investigation we simplified the problem by choosing the alternative approach suggested by Schnute (1994) where the process error deviations are treated as constrained parameters (his errors-in-variables paradigm). This approach required estimating a relatively large number of parameters explicitly, but the implementation was more straightforward.

We specified the likelihood, *P,* as

$$P \propto \prod_{k=1}^{nspp} \prod_{t=1}^{T} \exp\left[\frac{\left(Y_{k,t} - \theta_{k,t}\right)^2}{2\sigma^2_{v_{k,t}}} + \frac{w^2_{k,t}}{2\sigma^2_{w_k}} + \frac{\delta^2_{k,t}}{2\sigma^2_{\delta_k}} \right]$$

where k subscripts each species group. We minimized the negative logarithm of this likelihood to obtain the parameter estimates. The model parameters are given as the initial biomass estimate, $\theta_{k,0}$ for the k^{th} species group, the amount that the projected biomass deviates from year to year (constrained by $\sigma^2_{w_k}$), $w_{k,t}$, and the amount that catch deviates each year (constrained by $\sigma^2_{\delta_k}$), $\delta_{k,t}$. For 6 species over the years from 1984-2000, the model has 96 parameters. The estimation was done using the automatic differentiation software ADModel Builder (Otter Research 1998). Marginal likelihoods for quantities of interest (e.g., exploitation rates) were approximated using the Monte Carlo Markov Chain algorithm (Gelman *et al.* 1995, Otter Research 1998).

Results

To illustrate the effect of the process error variance $\sigma^2_{w_k}$ on biomass trajectory, we present species groups with a high and low variance (Fig. 3). For the high process variance case, the historical estimates have little or no effect on the most recent estimate. This case is most similar to the management practice of using the most recent biomass for ABC recommendations. Note that the uncertainty increases dramatically as the model is projected beyond the most recent 1996 survey estimate. For the low process variance case (bottom panel, Fig. 3), the current estimate is weighted quite heavily by the historical estimates and the trajectory is much more like a mean over all years. This outcome is most like the management practice of setting the ABC based on some weighted average over all surveys.

The actual species groups estimates and their 95% confidence bounds are given in Fig. 4. The uncertainty in estimates for the squid and octopus groups were the greatest reflecting the relatively high observation and process errors. Sharks and skates have slowly increasing trends which fail to fit closely the observed biomass estimates since those species are unlikely to have high fluctuations in biomass based on the relatively low reproductive rates. The fact that the survey estimates are substantially higher than the estimated trajectory highlights that there may be problems with model specification. For example, if there were a significant change in the way the surveys were conducted since 1993 regarding sharks and skates, then that change has not been modeled (though a term could easily be added to that effect). Alternatively, we may have simply underestimated the rate that skates and shark populations can change (via the process error variance).

Estimates of the historical exploitation rates for each of the species groups are fairly uncertain, as expected given the quality of information provided (Fig. 5). The exploitation rates are mostly below 10% for all the groups with a median value of less than 3%. In some years the point estimates are much higher than adjacent years (e.g., sharks and skates in 1993). This appears to be linked to the algorithm for estimating catches since in some years, a high extrapolation number may result from a relatively small number of tows.

Octopi represent an obvious exception to the pattern of low historical exploitation rates (Fig 5). The estimated mean annual exploitation rates for octopi are very close to the OFL based on an M of 0.3. The analysis also gives the dubious result that the exploitation rate for octopi could have exceeded 100% in 1997. We believe that these results reflect the inadequacy of our available biomass estimates for octopi, and not the true exploitation rates for this species group. It is important to note that the majority of octopus catch is observed in pot fisheries, while catches in commercial bottom trawls are very small, similar to catches in our survey gear. It appears that pot gear samples the octopus population much more efficiently than trawl gear, so that the catch estimated from aggregated gear overestimates exploitation rates.

Assessment of the uncertainty in the projection year (2000) exploitation rate shows that there is a relatively low probability that it will exceed 5% for all species groups except octopi (Fig. 6). Recall from above that the interpretation of the survey and catch estimates for octopi and, to a lesser extent, squid and smelts, are tenuous at best. We recommend caution when interpreting these results.

Since the values we selected for the process error variance were somewhat subjective, we evaluated the sensitivity to the assumed values. Similarly, it could be argued that the sample variances from the swept-area survey method are underestimated. Therefore, we simulated a biomass time series for a species with relatively high observation and process error (similar to octopus), and doubled the coefficient of variation in both the observation and process errors to see the effect it has on projected exploitation rates. As expected, the original variances assumed suggested provided greater confidence in the estimated exploitation rate (Fig. 7). Interestingly, the median exploitation rates for the low and high variance cases were about 13% and 10%, respectively. However at the upper tail, the 10% probability of exceeding a given rate occurs at exploitation rates of about 23% and 40%, between the low and high variance case.

Discussion

The method we present is intended as a first step towards using *some* biological information on "other species" groups and sub-groups via the values for $\sigma^2_{w_k}$. The choices for these values reflect some subjective decisions. Perhaps to move further from the subjective aspect of selecting process error variances more elegant methods incorporating data from other areas and species could be used. Gelman *et al.* (1995) present some methods for these types of meta-analyses using hierarchical Bayesian methods. This would presumably involve the notion that values for the process errors themselves arise from a separate, hyper-distribution.

Through these types of analyses, we also hope to provide some scientific bases for future directions in the development of fisheries management plans. Early on in the process of creating management plans it is critical to understand where information is most critically lacking. Our analyses show important differences between species groups, and in particular the inadequacy of the triennial bottom trawl survey cephalopod biomass estimates.

This type of approach is useful in other important areas of fisheries management. For example, the problem of apportioning quotas by management areas within a single stock is typically based on some relative abundance by area from a survey. Unfortunately, the variances of the sub-areas are always higher than for the stock as a whole. Simply dividing the quota proportionately among the most recent biomass estimates may have undesirable side effects like actually overfishing certain areas and creating less stability of area-specific harvests to the fishery. Using the equations above and changing the notation so that the index k represents "area" instead of "species group" will achieve the desired effect. In this case, the values selected for $\sigma^2_{w_k}$ will be related to the movement propensity of the species (scaled appropriately for the size of the areas). A similar weighting scheme (though somewhat more *ad hoc*) has been used in recent years for sablefish and some rockfish species in the GOA.

References

Collie J.S. and M.P. Sissenwine, 1983. Estimating population size from relative abundance data measured with error. Can. J. Fish. Aquat. Sci. 40: 1871-1879.

Gelman, A, J.B. Carlin, H.S. Stern, and D.B. Rubin. 1995. Bayesian data analysis. Chapman and Hall. London. 526 p.

Kimura, D.K., J.W. Balsiger, and D.H. Ito. 1996. Kalman filtering the delay-difference equation: practical approaches and simulations. Fish. Bull. 94: 678-691.

Meinhold, R.J. and N.D. Singpurwalla. Understanding the Kalman filter. Amer. Statist. 37:2 123-127.

Pella, J.J., 1993. Utility of structural time series models and the Kalman filter for prediction consequences of fishery actions. *In* G. Kruse, D.M. Eggers, R.J. Marasco, C. Pautske, and T.J. Quinn II (eds.)

Restrepo, V.R., G.G. Thompson, P.M. Mace, W.L. Gabriel, L.L. Low, A.D. MacCall, R.D. Methot, J.E. Powers, B.L. Taylor, P.R. Wade, and J.F. Witzig, 1998. Technical guidance on the use of precautionary approaches to implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act. NOAA Technical Memorandum NMFS-F/SPO-31.

Schnute, J.T. 1994. A general framework for developing sequential fisheries models. Can. J. Fish. Aquat. Sci. 51: 1676-1688.

Thompson, G. G. 1998. Application of the Kalman filter to a stochastic differential equation model of population dynamics. *In*: Statistics in Ecology and Environmental Modeling 2: Decision Making and Risk Assessment in Biology, D. J. Fletcher, L. Kavalieris, and B. J. Manly (Eds), 181-203. Otago Conference Series No. 6. University of Otago Press, Dunedin, New Zealand.

FIGURES

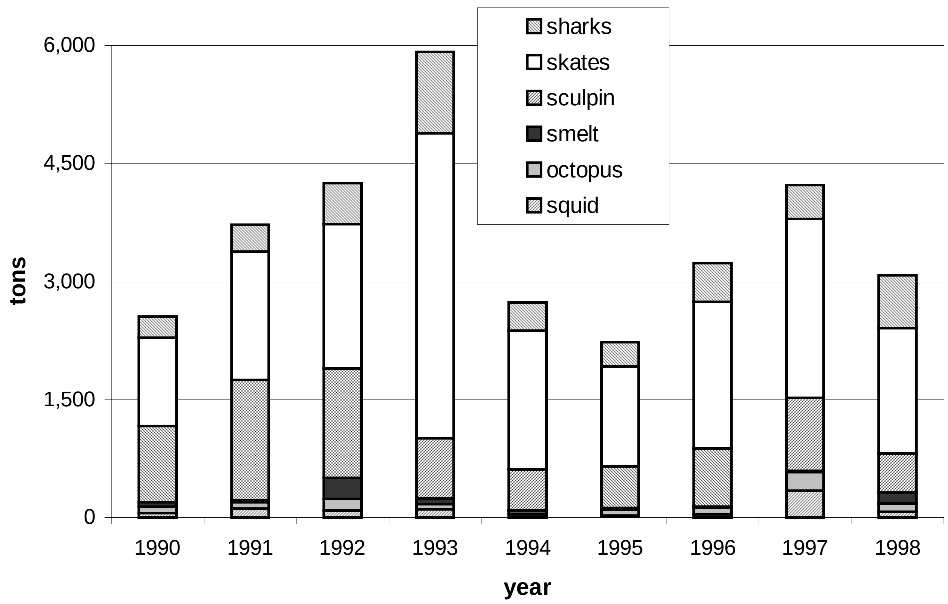

Figure 1. Estimated catch by species group, 1990-1998.

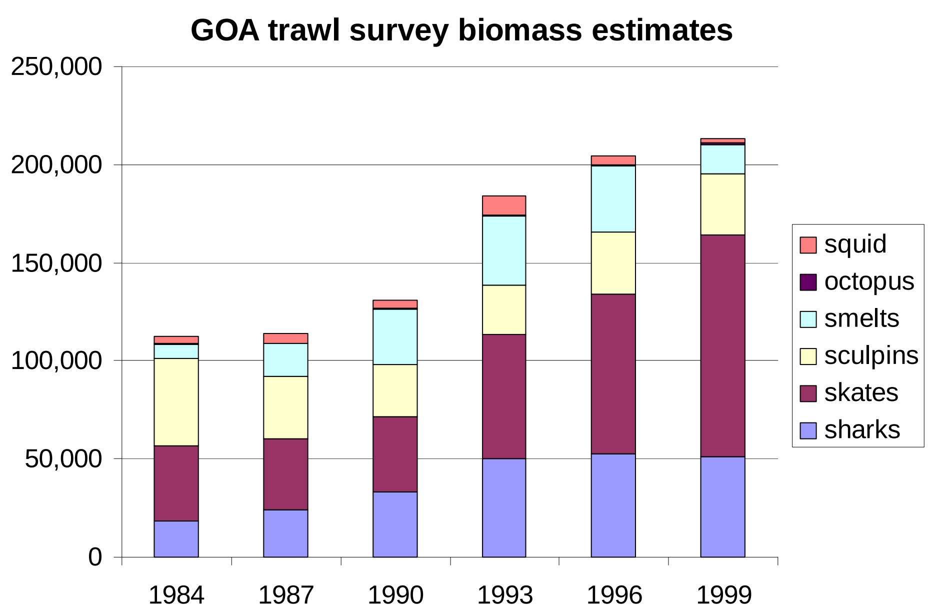

Figure 2. Estimated biomass by species group, 1984-1999 from NMFS triennial bottom trawl surveys.

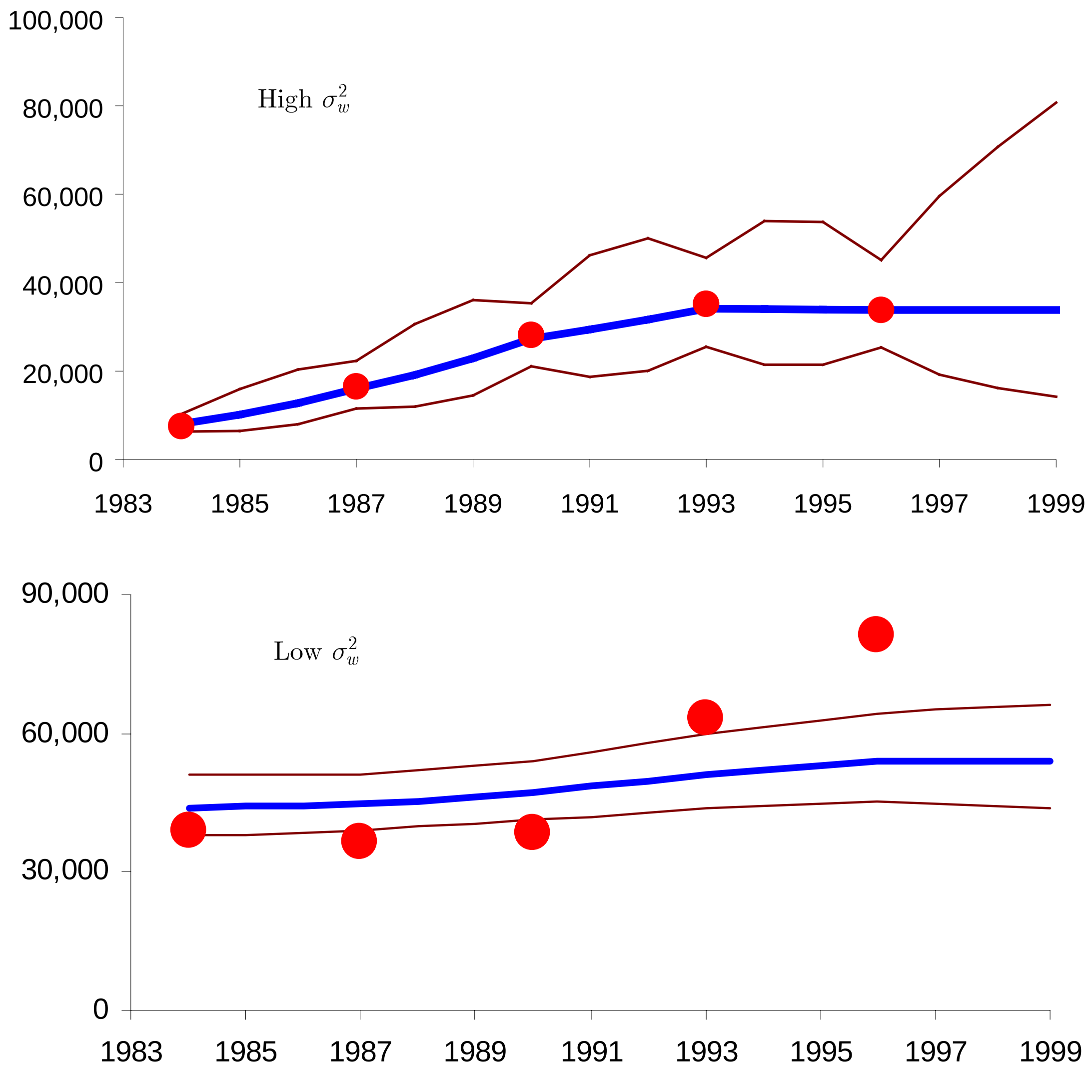

Figure 3. A typical species biomass trajectory plotted with high- (top panel) and low- (bottom panel) process variability in life history characteristics. Dots represent survey estimates; lines represent the estimated abundance and upper and lower 95% confidence bounds.

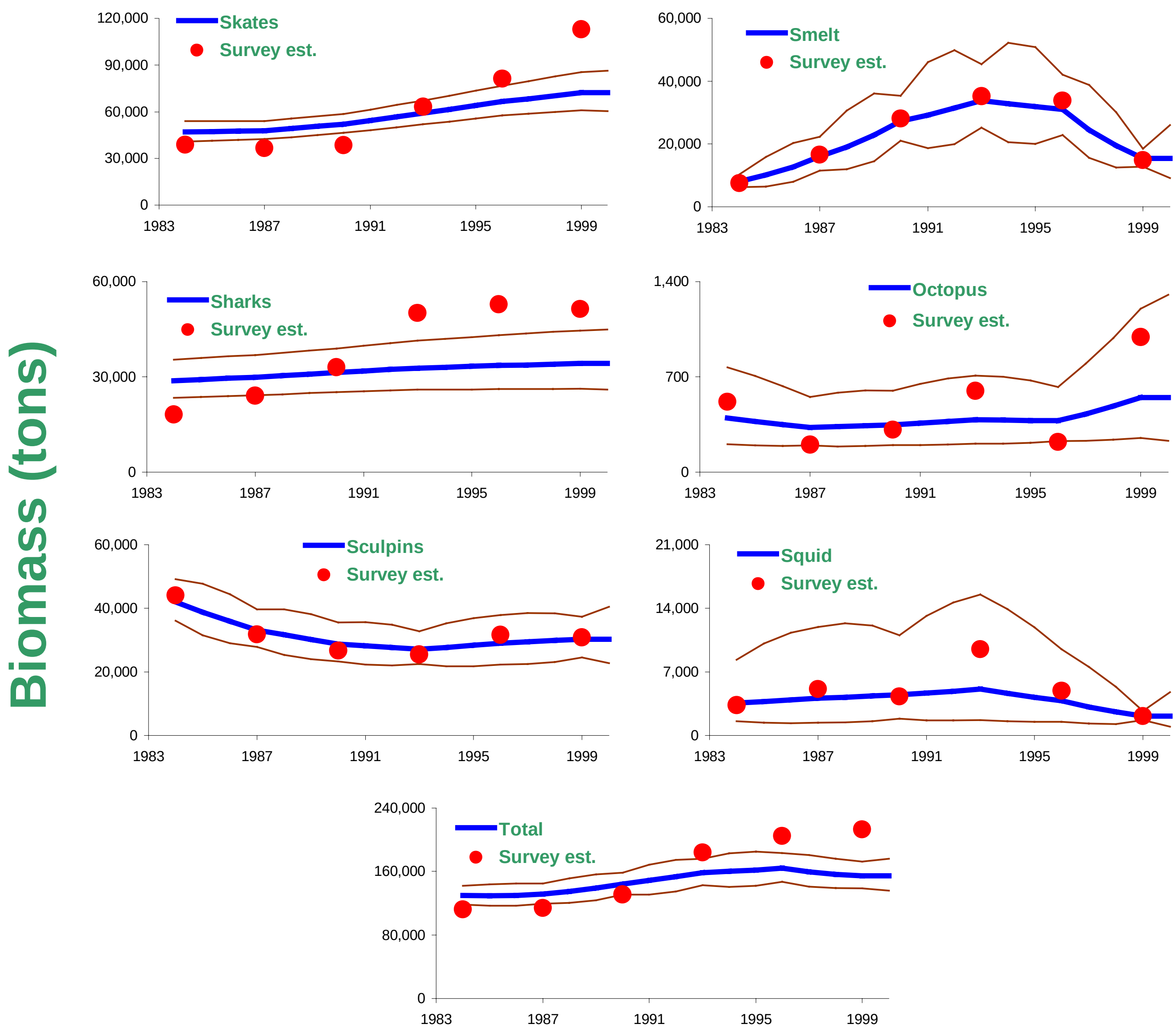

Figure 4. Model biomass trends plotted by species groups, 1984-2000. Dots represent survey estimates; lines represent the estimated abundance and upper and lower 95% confidence bounds (variances as derived from the delta method).

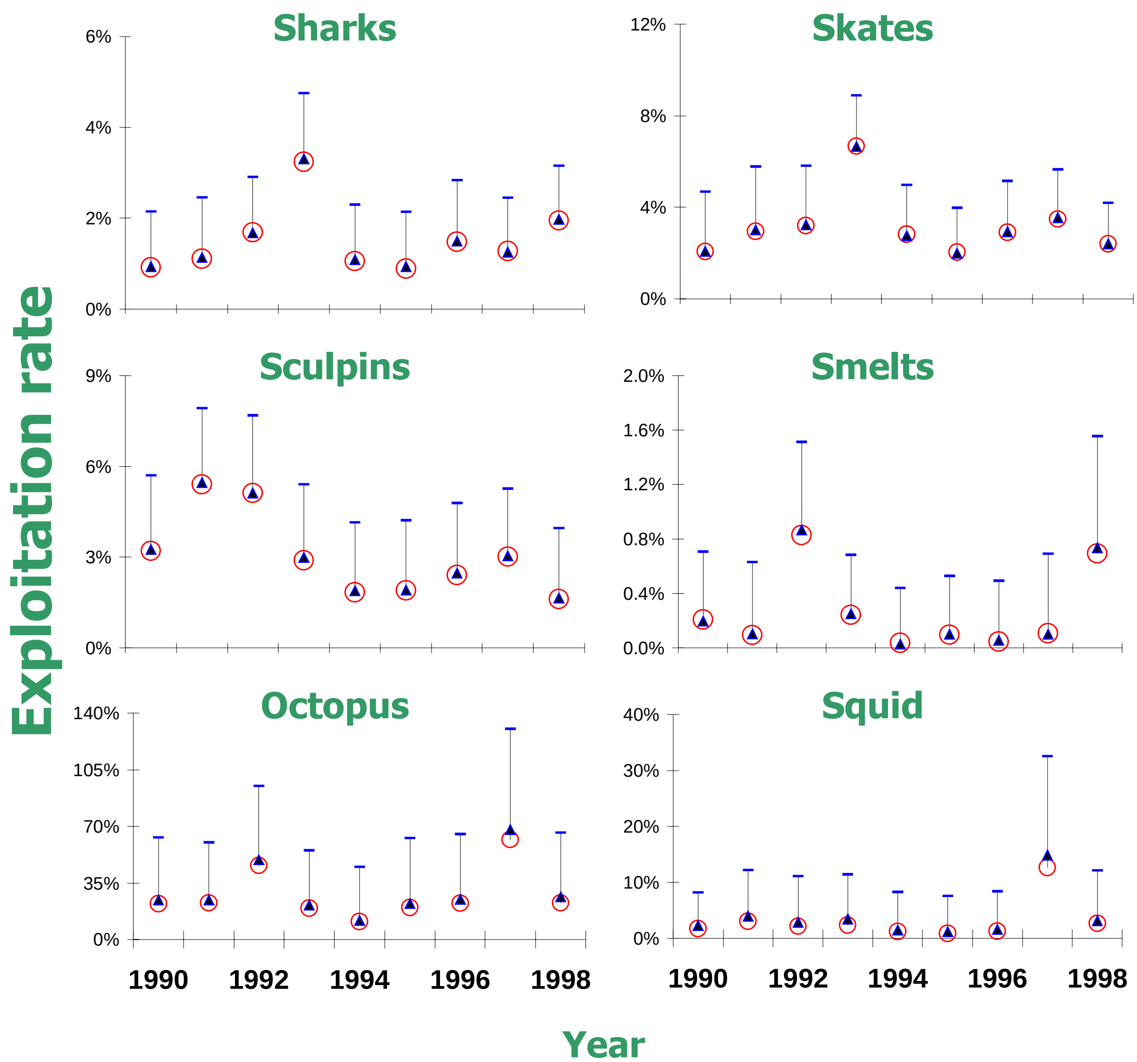

Figure 5. Estimates of historical exploitation rates by year and species group. The open circles represent the median value, the triangles represent the mean, and the upper bar is the upper 95th percentile.

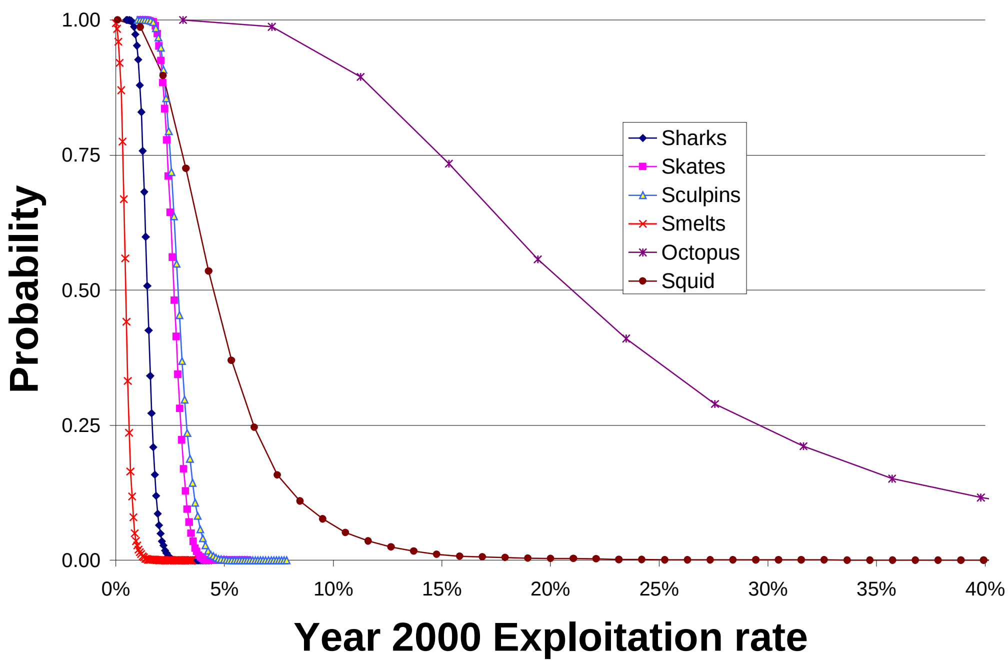

Figure 6. Cumulative probability of exceeding projected exploitation rates for the year 2000 by species group. These results assume that the future catch will be the same (in expectation) as the average catch over 1990-1998.

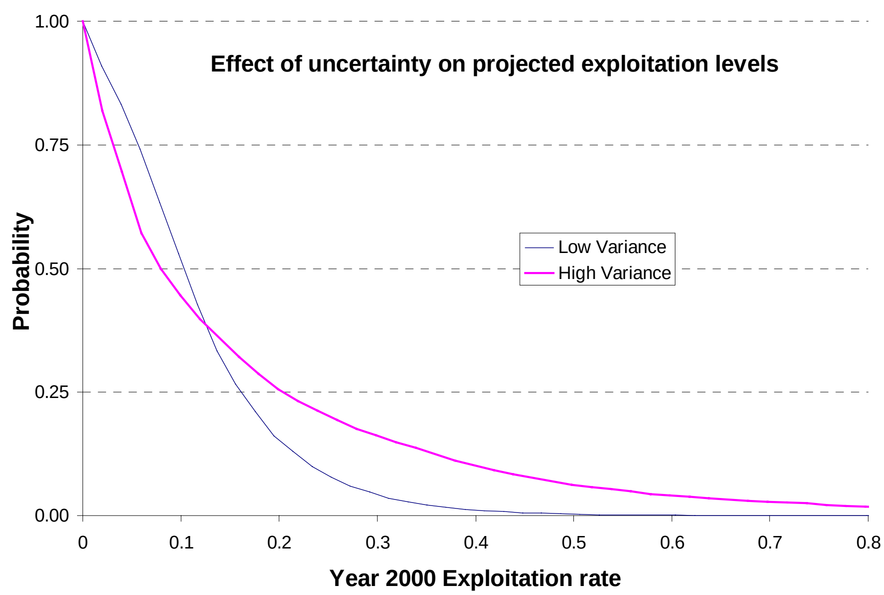

Figure 7. Sensitivity projected 2000 exploitation rates to variance assumptions for an octopus-like species group. We assumed that the future catch will be the same (in expectation) as in 1998.

Tables

Table 1. Estimates of catch (tons) of "other species" groups based on NMFS observer and blend data.

Year	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Total Other
1990	274	1,124	969	54	79	60	2,560
1991	340	1,630	1,532	25	79	117	3,723
1992	517	1,835	1,392	264	151	88	4,248
1993	1,027	3,882	761	78	63	104	5,915
1994	360	1,770	514	15	39	39	2,737
1995	308	1,273	529	25	71	25	2,230
1996	484	1,868	739	17	79	42	3,229
1997	436	2,268	928	20	236	339	4,226
1998	669	1,596	502	135	105	74	3,081

Table 2. NMFS triennial trawl survey biomass estimates (top) and associated coefficients of variation (CV; bottom) for 1984-1996.

Biomass	**Sharks**	**Skates**	**Sculpins**	**Smelts**	**Octopus**	**Squid**	Total
1984	18,156	38,761	44,097	7,536	516	3,308	112,374
1987	24,049	36,398	31,742	16,526	203	5,083	114,000
1990	33,063	38,492	26,708	28,145	312	4,309	131,028
1993	50,025	63,219	25,460	35,210	599	9,476	183,989
1996	52,883	81,160	31,691	33,792	222	4,911	204,659
1999	51,355	112,935	30,827	14,890	992	2,096	213,094
CV							
1984	26%	17%	8%	14%	33%	14%	8%
1987	32%	13%	12%	19%	69%	31%	9%
1990	25%	17%	18%	13%	52%	16%	9%
1993	17%	12%	13%	16%	47%	13%	7%
1996	43%	11%	30%	15%	60%	14%	13%
1999	17%	9%	11%	10%	28%	12%	6%

Table 3. Selected estimates of biological trend parameters and description of reliability for information sources used in the model by species groups.

Species group	Natural population variability	Annual change potential (w_t)	Abundance trend reliability	Catch estimation reliability	Natural Mortality
Sharks	slow	3%	Mod-poor	OK	0.09
Skates	slow	3%	OK	OK	0.1
Sculpins	slow-mod	10%	OK	OK	0.15
Smelts	mod-high	25%	Poor	Mod-poor	0.3
Octopus	moderate	20%	Poor	Poor	0.3
Squid	rapid	40%	Poor	Mod-poor	0.4 - 1.6

Table 4. Natural mortality (M) estimates for other species groups

Group	Species	Estimate	Reference
Squid	*Todarodes pacificus*	0.4308	Osako and Murata, 1983
Octopus	*Octopus vulgaris*	0.5	Sato and Hatanaka, 1983
Smelt	*Mallotus villosus*	0.42	Anderson, 1990
Sculpin			(None found)
Skate	*Raja erinacea*	0.4	Sosebee, 1998
Shark	*Squalus acanthias*	0.094	Anderson, 1990
		0.09	Sosebee, 1998
	Lamna nasus	0.18	Anderson, 1990